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President of New England Water Works Association,
1921.

New England Water Works Association

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

STANDARD SCHEDULE FOR GRADING CITIES AND TOWNS OF THE UNITED STATES WITH REFERENCE TO THEIR FIRE DEFENSES AND PHYSICAL CONDITIONS.

JOHN S. CALDWELL.*

[*November 10, 1920.*]

This Schedule for Grading Cities and Towns of the United States with Reference to their Fire Defenses and Physical Conditions is not entirely new to members of this Association, as you have a special committee who have made progress reports from time to time, with especial reference to the water supply, and recommended certain changes which have been later incorporated into the Schedule, but I believe this is the first time that the Schedule has been presented to you in its entirety, and while your particular interest is naturally in the water-supply section, I think the other portions will prove to be interesting, as it will indicate the extent and degree of the so-called measuring stick which has been devised for determining the relative value of these various subjects.

I think that it will be time well spent if I go back and outline the causes which have led up to the need of this Schedule. In the past it had been deemed sufficient in the determining of insurance rates if a city or town had a water-works system, with hydrants in evidence; a fire department with apparatus, equipment, and men to handle same; a fire-alarm system, police department, building laws, etc.; but it had never been considered necessary to attempt to go into any great detail regarding the efficiency of such protection.

The natural result of such a procedure is apparent to all of you, namely, that inconsistencies existed which brought about rates which were not comparable with existing conditions, some being too high and others too low, and in general brought about a condition of affairs which was unsatisfactory to both the municipalities and the insurance interests.

In New England we realized the necessity for a change, and in 1913 put into effect our classified system of rating for dwelling-house property, which many of you are familiar with, whereby we graded the cities and

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towns of New England on a 200-point basis, allotting the 200 points to a perfect or standard city or town according to the value of its water supply, fire department, fire-alarm system, ordinances, etc., the class being determined by certain limitations of the points allotted.

Meanwhile the National Board of Fire Underwriters were engaged in the compiling of a universal schedule which could be adopted all over the country, so that uniform results might be obtained in arriving at the value of the fire protection facilities of the various cities and towns. In the working out of this problem the advice of water-works officials, fire chiefs, insurance organizations, etc., was obtained, so that the final result might be said to represent the best opinion obtainable on the various subjects considered.

It is, of course, not to be claimed that the Schedule is perfect, as the practical application has shown that various changes have been necessary to meet certain local conditions; but we do feel that by the results so far obtained it is a forward step in the right direction and is a vast improvement over the old method.

It is this Schedule which was adopted by the National Board of Fire Underwriters in 1916, and by the New England Insurance Exchange in 1918, that I will attempt briefly to describe to you.

The grading schedule is based upon the plan of assigning to the various features of fire defense found in cities of the United States, points of deficiency depending upon the extent of variance from standards formulated from a study of conditions in more than 300 cities; the natural and structural conditions which increase the general hazard of cities, and the lack of laws or of their enforcement for the control of unsatisfactory conditions, are graded in the same way. The sum of the maximum points of deficiency totals 5 000 and is divided in accordance with the relative values of the features considered as given below.

RELATIVE VALUES.

			Points
Water supply	Engine stream basis		1 700
	Hose stream basis	2 000	
Fire Department	Engine stream basis		1 500
	Hose stream basis	1 200	
Fire alarm			550
Police			50
Building laws			200
Hazards			300
Structural conditions			700
			5 000

It is recognized that climatic conditions affect fire losses, by reason of the frequency of fires due to the heating hazard, by retarding the response of fire apparatus, by hampering effective fire fighting during cold weather and storms, by the increase in combustibility due to hot and dry weather,

and by the greater probability of fires spreading at time of high winds. These elements are to a greater or less degree common to the whole country, and therefore no deficiency is considered in the Schedule for normal climatic conditions. Some sections of the country, however, are subject to abnormal climatic conditions, and to cities in these sections a super-deficiency is applied, which I will describe later. This super-deficiency is to be added to the deficiency determined by the application of the Schedule proper.

A good water supply in connection with a poor fire department, or vice versa, is of less value than if both are good. In recognition of this, a modification of the better one of the two features is made in accordance with a plan which I will outline later to you.

In determining the points of deficiency to be applied to many of the items it appears reasonable to use a graduated scale of points, depending upon the per cent. of deficiency, with a lesser increment for the first 30 per cent. than for the remainder; that is, a deficiency of 10 per cent. in good or moderately good conditions has less actual effect than where conditions are poor. Such a scale has been prepared as shown below; either the full scale, a multiple or a fractional part thereof is used, depending upon the relative weight or importance of the item under consideration.

Deficiency Scale.

	0%.	10%.	20%.	30%.	40%.	50%.	60%.	70%.	80%.	90%.	100%.
0%	0	10	25	45	67	90	112	134	156	178	200
1%	1	12	27	47	70	92	114	136	158	180	
2%	2	13	29	50	72	94	116	138	160	182	
3%	3	15	31	52	74	97	119	141	163	185	
4%	4	16	33	54	76	99	121	143	165	187	
5%	5	18	35	57	79	101	123	145	167	189	
6%	6	19	37	59	81	103	125	147	169	191	
7%	7	21	39	61	83	105	127	149	171	194	
8%	8	22	41	63	85	108	130	152	174	196	
9%	9	24	43	65	88	110	132	154	176	198	

Where quantity or numbers cannot be used as the basis, the degree of deficiency is graded approximately as follows: Slight, 10 per cent.; moderate, 25 per cent.; considerable, 50 per cent.; serious, 75 per cent.; and total, 100 per cent. In considering the degree of such unreliability, the size of the community is considered; that is, conditions which in a city would be considered as serious would in a small town be only moderate or considerable because of the less general probability of a fire occurring.

It was very early recognized, after the Schedule had been applied to representative cities and towns, that the application of the items under fire department produced deficiency charges in small municipalities which were out of proportion with the actual experience found in such localities, due to the infrequency of fires, and it was decided to deduct from the total points of deficiency under fire department, 10 per cent. for each 1 000 population below 10 000, for certain items which were not as important in the small communities as in the larger cities.

After arriving at the total number of points of deficiency, the class of the city or town is determined from the following table.

Class Division.

A first-class city or town is one receiving	0 to 500 points of deficiency.
A second-class city or town is one receiving	501 to 1 000 points of deficiency.
A third-class city or town is one receiving	1 001 to 1 500 points of deficiency.
A fourth-class city or town is one receiving	1 501 to 2 000 points of deficiency.
A fifth-class city or town is one receiving	2 001 to 2 500 points of deficiency.
A sixth-class city or town is one receiving	2 501 to 3 000 points of deficiency.
A seventh-class city or town is one receiving	3 001 to 3 500 points of deficiency.
An eighth-class city or town is one receiving	3 501 to 4 000 points of deficiency.
A ninth-class city or town is one receiving	4 001 to 4 500 points of deficiency.
A tenth-class city or town is one receiving	more than 4 500 points; or without a water supply and having a fire department grading tenth class; or with no fire protection.

I will now take up in detail the various subjects which are considered in the Schedule, relating to the water supply.

Water Supply.

Item.

1. Appointment of employees.
2. Efficiency of executive.
3. Records and plans.
4. Emergency repair provisions.
5. Receipt of alarms by department.
6. Normal adequacy of entire system.
7. Reliability of source of supply.
8. Sufficiency of reserve pump capacity.
9. Sufficiency of reserve boiler capacity.
10. Condition and arrangement of equipment.
11. Fuel supply or electric power.
12. Construction of pumping station.
13. Fire protection of pumping station.
14. Hazards of pumping station.
15. Exposures to pumping station.
16. Reliability of supply mains as affecting adequacy.
17. Reliability of installation of supply mains.
18. Completeness of arterial system.
19. Reliability of installation of mains.
20. Effect of small mains in the high-value district considered.
21. 4-in. mains in system.
22. Dead ends — 4- and 6-in. mains.
23. Completeness of gridiron of 6-in. mains.
24. Quality and condition of pipe.
25. Electrolysis.
26. Spacing of gate valves.
27. Condition of gate valves.
28. Distribution of hydrants in the high-value district considered.
29. Ditto in residential districts.
30. Condition of hydrants.
31. Size and design of hydrants.
32. Valves on hydrant branch.

In order to ensure efficient operation, employees on municipal systems should be under adequate civil service rules with tenure of office secure, except that, in cases of long tenure of office, an efficient organization would be considered the equivalent.

The chief executive — that is, the superintendent or chief engineer — should be competent and qualified by either experience or education, but preferably both, to efficiently fill the office.

Records and plans of the supply works, pumping stations, and distribution system, together with complete records of the operation of the system, should be in convenient form, safely filed, indexed, and kept up to date.

Emergency crews shall either be on duty at all times, or quickly available, with an emergency wagon loaded with the necessary tools. At least one responsible employee familiar with the system should respond to fire alarms in high-value districts and second alarms elsewhere.

Alarms of fire should sound in some quarters of the department, also in pumping stations where pressures are raised or pumps started to furnish fire service; telephone service to pumping station shall be considered as 25 per cent. of the total requirements, and, in the event of a lack of operating force on duty, this is considered as equivalent to deficient alarm service.

The item of adequacy of the entire system is one of the most important in the whole Schedule, as here one must determine as to whether the source, including the entire supply works, has the normal ability to maintain maximum consumption demands and fire flow.

In considering the deficiency under this item, the results obtained at fire-flow tests in the most favorable location in the high-value district is used as a basis in making calculations as to the probable deficiency under maximum consumption conditions, due allowance being made for any emergency supply. The extent of the deficiency of each part of the supply works must be considered and the percentage of the most serious used.

Cities are considered on an engine basis if the fire flow available at pressures permitting direct hydrant streams does not exceed actual engine capacity plus one third of the required fire flow, assumed to be as waste at time of fire, and the fire flow to be that obtained at the weakest part of the high-value district and at time of maximum consumption.

Allowance is also made on the ability of a system to deliver a fire supply on small fires direct without the use of engines, which increases the speed of operation of the fire department, even when full engine capacity is available.

Following is a table of required fire flow based on the population but modified by the individual characteristics of construction and hazards of the particular city or town under consideration. This table includes a probable loss from broken connections incidental to a large fire, and is based on the formula $G = 1020\sqrt{P}(1 - .01\sqrt{P})$, where G = gallons per minute

and P = population in thousands; but in all cases consideration must be given to local conditions.

TABLE OF REQUIRED FIRE FLOW.

Population.	Required Fire Flow. Gallons per Minute for Average City.	Population.	Required Fire Flow. Gallons per Minute for Average City.
1 000	1 000	28 000	5 000
2 000	1 500	40 000	6 000
4 000	2 000	60 000	7 000
6 000	2 500	80 000	8 000
10 000	3 000	100 000	9 000
13 000	3 500	125 000	10 000
17 000	4 000	150 000	11 000
22 000	4 500	200 000	12 000

Over 200 000 population, 12 000 gal. a minute, with 2 000 to 8 000 gal. additional for a second fire.

In residential districts: For villages or towns under 10 000 population, 500 to 1 000 gal. a minute, where the district is not congested; for cities over this population, or where the district is congested, 1 000 to 3 000 gal. a minute, with up to 6 000 gal. a minute in densely built sections of 3-story buildings.

In considering the reliability of source of supply the effect on adequacy must be considered for such items as frequency and duration of droughts, physical condition of intakes, danger from earthquakes, floods, forest fires, ice dams and other ice formations, silting up or shifting of channels, absence of watchmen where needed, etc.

The pumping capacity must be such that with the two largest pumps out of service the remainder in connection with such storage as may be available must be sufficient to maintain maximum consumption and fire flow at required pressure. For cities requiring less than 5 000 gal. fire flow, the relative infrequency of fires is assumed as offsetting in part the probability of a serious fire occurring at times when pumps are out of service, and allowance is made accordingly.

In cases where both low-lift and high-lift pumps are provided and reliability of supply is dependent on each, they must be considered separately and the sum of the points of deficiency applied.

Boiler capacity with a reserve of one quarter the entire capacity, and in any case at least one boiler must be sufficient to operate all machinery and the pumps required to maintain maximum consumption and fire flow with allowance made for storage. Nominally, there must be sufficient boiler capacity kept under at one half required steam pressure to deliver full requirements in connection with storage for a period of two hours. With sufficient stack or forced draft capacity, an overload of 50 per cent. over the maker's rating is used for fire tube boilers and 100 per cent. for water tube.

The following forms and combinations of plant equipment, if of modern design and well constructed and installed, are assumed as approximately equal, advantages of each, if any, being in the order of their naming:

a. Centrifugal or reciprocating pumps driven by steam engines.

b. Centrifugal or reciprocating pumps driven by electric motor.

c. Pumps operated by water power.

d. Centrifugal or reciprocating pumps operated by internal combustion engines approved for this service. Duplicate ignition parts to be on hand for each engine. Adequate provision to be made for starting engines cold at least six times in rapid succession.

All equipment must be of a design applicable to the service; service record in the plant under consideration and in similar plants shall be considered, and actual operating conditions observed. Pumps to be free from knock, with low slip, and capable of operating at full speed. Boilers to be well set, in good condition and with proper semi-annual inspection service; stacks shall be substantially installed. Electrical equipment for power to be in accordance with National Electrical Code, and not liable to injury by water spray. Water-power equipment must be accessible and properly safeguarded; operating force to be competent.

A minimum of five days' coal supply should be provided; where long hauls, condition of roads, climatic conditions or other causes make a longer interruption of delivery possible, a greater storage should be provided. Gas supply should be from two independent sources or from duplicate gas producer plant, with a storage of at least twenty-four hours' gas supply. Oil supply should be from underground storage of at least five days' capacity, with force feed to engine or boiler. Unreliability of gas or oil supply to boilers may be lessened by proper provisions for the use of coal. Water for power should equal at all times that necessary to meet maximum requirements and should have proper flood and ice control.

Steam piping (or gas or oil piping with internal combustion engines or to boilers) or electric transmission lines should be so arranged that a failure in any line, or the renewal of a valve, transformer or oil pump, would not prevent maintaining in connection with storage, maximum domestic consumption for two days, and fire flow for ten hours. Overhead electric lines introduce a degree of unreliability which may be in part offset by storage; consideration in connection with such lines shall be given to number and duration of wind, sleet and snow storms, character of poles and wires, character of country traversed, effect of forest fires and ease of and facilities for repairs; the use of the same transmission line from transformer or switchboard by other plants introduces a hazard of short circuit or prior use of power, and may be considered as the equivalent to the use of overhead lines in applying the Schedule.

Pumping stations and other portions of the plant should contain no combustible material in their construction; otherwise an automatic sprinkler equipment should be provided; outside hydrants and hose, inside standpipes and hose, and chemical extinguishers should be provided. Public fire station, if within three quarters of a mile, shall be considered as giving about one-half protection. If pumping station is not fireproof,

the several sections, particularly any with high potential generating equipment, shall be separated by parapeted fire walls and openings protected by standard fire doors and wire glass in metal frames. Station shall be protected against exposures. Electric wiring shall be in accordance with the National Electrical Code, and all internal hazards safeguarded.

Under the item of reliability of supply mains as effecting adequacy will be included any and all pipe lines or conduits on which supply to the distribution system is dependent; suction or gravity lines to pumping station, flow lines from reservoirs, force mains, etc., are included and a system may have one or all of these as part of it. Consideration must be as to greatest effect on maximum consumption and fire flow at required pressure that a break could have. If remaining pipes and storage cannot deliver even maximum consumption, allowance is made for only that amount available at required pressure. In applying, all mains which deliver from a source of supply or of storage to the high-value district must be considered. Aqueducts, of good design and of substantial construction, such as masonry or concreted steel, if properly installed, shall be considered sufficiently dependable as not to require duplication, and no application will be made as to the effect of a possible break.

Under the assumption of the most serious single break, when capacity of mains from the source of supply is less than maximum consumption, deficiency shall be considered as offset by storage when the difference between maximum consumption and the capacity of the mains is equaled by one fifth the storage after deducting fire flow for ten hours, except as restricted by the capacity of the mains from the storage. When capacity of the mains from the source of supply is more than maximum consumption, the excess capacity plus 2.4 times the storage shall be considered as offsetting deficiency if equal to the fire flow in million gallons a day. The effect of a break in suction or discharge headers, lack of by-passing or poorly gated by-pass or arrangements at any reservoir, filter, etc., poorly arranged cross-connections, etc., must be considered; also features which would tend to cause or prevent an interruption of service, such as length of line, and two or more lines from the same or different sources or from storage.

Deficiency for each individual possible break is considered, and charge made for the case giving the maximum total number of points, including the increase due to distance.

In considering the reliability of installation of supply mains it is assumed that they must be in good condition and reliable; cast iron, wrought iron, wood stave, and masonry conduit have been found satisfactory, in various places and under certain conditions; service records and general conditions must be considered. Mains should be laid so as not to endanger each other, and their failure at stream and railroad crossings and other points where physical conditions are unsatisfactory should be guarded against; they should be cross-connected and gated about

once a mile, and equipped with air valves at the high points and blow-offs at the low points.

The general arrangement of valves, specials, and connections at cross-overs, intersections, reservoirs, and discharge and suction headers must be considered with the view to quickness in shutting down breaks; the need of check valves on supply or force mains, and other arrangements to prevent emptying of reservoirs at time of a break in a main must be considered, as well as ease of repair in case of breakage. If there is more than one main, and conditions do not affect all, application is made in proportion to the carrying capacity affected and the degree of unreliability.

The arterial system includes the main arteries and secondary feeders which extend throughout the system. These feeders should be of sufficient size considering their length and the character of the sections served to deliver the fire flow necessary for the district. The basis of deficiency is applied by the results obtained in the fire-flow tests and general consideration of the arrangement.

Mains of the arterial system should not be laid across filled ground, and should have special construction at railroad crossings and near bridge abutments, and should be so gated that not more than one quarter of a mile within the distribution system will be affected by a break. All mains should have sufficient cover to prevent freezing, with a minimum cover of 2 ft. to prevent injury from traffic.

In considering the minor distributors and gridiron system, 6 in. is considered the minimum size satisfactory for hydrant supply in residential districts, to be closely gridironed with 6-in. cross-connecting mains at intervals not exceeding 600 ft., or where initial pressures are high a satisfactory gridiron may be obtained by a liberal per cent. of larger mains cross-connecting the 6-in. at greater intervals; in new construction, 8-in. should be used where dead ends and poor gridironing are likely to exist for some time, and 6-in. only where blocks are 600 ft. or less in length. In high-value districts, the minimum size to be 8-in., with cross-connecting mains at distances as given above; 12-in. and larger mains to be on the principal streets and for all long lines not cross-connected at frequent intervals.

The mains of the distribution system should be of satisfactory quality and properly tested for soundness and tightness of joints. The use of cast-iron pipe under pressure double that specified for the class is considered as introducing an unreliable feature, particularly where pressures are raised for fires; tests before back-filling the trench and service records of several years may, however, be assumed as offsetting this defect in part.

Electrolysis conditions should be studied, and methods of prevention applied.

The distribution system should be equipped with a sufficient number of gate valves, so located that no single case of accident, breakage, or repair to the pipe system exclusive of arteries will necessitate the shutting from

service a length of pipe greater than 500 ft. in high-value districts, or greater than 800 ft. in other sections, and will not result in shutting down an artery. All valves to be inspected yearly, and large valves more frequently, and be kept in good condition; the presence of some valves operating in opposite direction is to be considered the equivalent of unsatisfactory condition, ranging from fair to poor, depending on the number and importance.

In considering hydrant distribution it is readily apparent that proper distribution depends first upon whether the system is on a direct hydrant or engine stream basis, realizing of course that wider distribution could be permissible where engines were ordinarily used than where hydrant streams were utilized, also that the fire flow required for the district is a determining factor, as the same distribution cannot be expected in a residential district as would exist in a manufacturing or mercantile section. We, therefore, determine what our required fire flow should be and then use the following table.

Engine Streams.

Fire Flow Required. Gallons per Minute.	Average Area per Hydrant. Square Feet.
1 000	120 000
2 000	110 000
3 000	100 000
4 000	90 000
5 000	85 000
6 000	80 000
7 000	70 000
8 000	60 000
9 000	55 000
10 000	48 000
11 000	43 000
12 000	40 000

Direct Hydrant Streams.

1 000	100 000
1 500	90 000
2 000	85 000
2 500	78 000
3 000	70 000
4 000	55 000
5 000 and over	40 000

Hydrants should be inspected in the spring and fall of each year; after use at fires during freezing weather and daily in high-value districts during protracted periods of severe cold.

The standard requirements for hydrants specifies that they should be able to deliver 600 g.p.m., with a loss of not more than $2\frac{1}{2}$ lb. in the hydrant and a total loss of not more than 5 lb. between the street main and hydrant outlet; they should have not less than two $2\frac{1}{2}$-in. outlets and

also a large suction outlet where engine service is necessary. They should also be of such a design that when the hydrant barrel is broken off the hydrant will remain closed. Street connection should be not less than 6-in. in diameter and should be gated. Flush hydrants requiring chucks to be screwed on are considered undesirable, especially in sections of the country subject to heavy snow storms, because of delay in getting into operation.

Buildings of fireproof construction, sprinklered brick buildings, fire breaks, fire barriers, and separate high-pressure fire systems designed to deliver capacity at 90 lb. hydrant pressure or more, form important mitigating features.

Credits.

The subjects considered under Credits are as follows:

Item.

21. Superior Construction and Protection.
22. Fire Engine Capacity where Water Supply at Direct Hydrant Streams is Adequate.
23. High-Pressure Fire System.

(*Note.* Items apply only to the high-value district considered.)

Buildings of fireproof construction and sprinklered buildings tend to offer a barrier against a spreading fire as well as offering the fire department a vantage point in preventing a fire from gaining conflagration proportions, and credits are allowed accordingly.

Where the full fire flow is available as direct streams either from a domestic water system or from a high-pressure system, the maintaining of engines in service, with adequate provisions for their response and operation, is considered an advantage as reducing the probability of a fire gaining headway in the interval of time necessary to control the flow from a broken main, and credit should be allowed accordingly.

A high-pressure system may have a gravity supply, direct pumpage supply, or a combination of the two. It may be a separate system for fire service only, or may be the extension of a high-service domestic supply into a low-service area, in which latter case only two thirds the actual fire flow obtainable should be assumed as available capacity. Fire-boat pipe lines should also be considered. To be standard, a high-pressure fire service must comply fully with the various items listed under Water Supply and be capable of delivering in the weakest part of the system the full fire flow required, including that necessary for a second fire, such supply to be available in an area equal to that served by the number of hydrants necessary to deliver this required fire flow when discharging 1 000 gal. a minute each. For standard fire service this quantity should be available at a residual pressure of 250 lb., residual pressures less than this down to 90 lb. as a minimum, permit classing a system as a high-pressure fire system, but of less worth in reducing the deficiencies in structural condi-

tions. Hydrants should be of ample dimensions, with four independently gated hose outlets and with 8-in. gated connections to the mains, to be so distributed that the entire area of the district is protected and the average area served per hydrant will not exceed 40 000 sq. ft.

Discussion.

A Member. I should like to ask Mr. Caldwell what he considers the pressure that would determine where a 4-in. line would be satisfactory in a gridiron connection.

Mr. Caldwell. We do not recognize 4-in. pipe as furnishing an adequate supply where fire streams are to be depended upon. In other words, there is a direct penalty in the schedule for the use of 4-in. pipe, but this charge is reduced where pressures are over a certain point. That is, we deduct a proportionate charge, realizing of course that the pressure will offset the 4-in. pipe to some extent.

A Member. About what pressure did you decide on?

Mr. Caldwell. That would vary with the character of the district. Of course, we consider in the average residential district where the system is on a direct hydrant stream basis that the full fire flow should be available at 60 lb., but in some districts we permit that as low as 50 lb. In high-value districts, we require it at 60 lb., unless a number of buildings are in excess of four stories in height, and then we require 75 lb.; on an engine basis the full flow is required at 20 lb.

Mr. Frank A. McInnes.* What is the status of the 4-in. hydrant?

Mr. Caldwell. I think I can answer Mr. McInnes's question. Of course in new installations you rarely find 4-in. hydrants, but you generally find some 4-in. mains in the distribution system, although, of course, 4-in. hydrants are not always attached to mains of that size. But where we have already penalized the distribution system for the existence of 4-in. mains we reduce the charge for 4-in. hydrants.

President Macksey. Where there are 4-in. hydrants, off of 4-in. mains, they are usually old installations, but there are a great many installations to-day where a hydrant with a 4-in. valve is connected with a 6-in. main; and I think that, regardless of the penalties which the Insurance Board may put upon them, that is going to continue, because the water-works people believe that in many cases it is the most practical thing for them to use, and the best investment.

Mr. George W. King.† If two of the pumping engines were out of commission what remains should be of a capacity of the required maximum amount at the fire streams?

Mr. Caldwell. Yes.

Mr. King. In other words, it is required to furnish enough pumping capacity in triplicate to supply the maximum demand.

* Division Engineer, City of Boston, Mass.

† Superintendent, Water Works, Taunton, Mass.

Mr. Caldwell. That would be in connection with available storage, which would always be included under the item of pumping equipment. We grade two ways on the pump capacity. We assume, first, that the largest unit in normal operation is out of commission, and figure the available capacity in connection with storage of the remaining units, and the full scale deficiency applied. Then we consider, with two units out, how much is remaining, but there we do not apply the full deficiency charge, feeling that that is more or less of a remote possibility, but still it is possible.

In this connection the New Bedford situation, I think, would be interesting for the Association to know; that is, the New Bedford system, of all of the systems in New England that we have applied the Schedule to so far, shows the least points of deficiency against it. As I recollect, it was sixty odd.

A Member. I think it is down to approximately thirty now.

Mr. Caldwell. The fact that this is out of a possible 1 700 points, shows that the Schedule is practical, and that we are not requiring things which are an impossibility, because here is one city that has met those requirements, and without any action on our part, because we have not put the Schedule into effect in New Bedford yet.

Mr. A. E. Martin.* Would you make a charge against the city that maintains a 4-in. parallel line in a street where there is already a main large enough to carry fire protection?

Mr. Caldwell. No, sir; we would not. We would consider the larger main; providing, of course, that that main was sufficient, or that the large main in connection with the 4-in. was sufficient to furnish the flow for that particular section.

Mr. Martin. I meant to have added that there was no hydrant, or would be no hydrants, connected with the 4-in. pipe.

Mr. Caldwell. No. We only penalize the 4-in. pipe where supplying hydrants. There would be no penalty attached to the use of 4-in. pipe for domestic service only.

Mr. Martin. In the case of this 4-in. parallel main being maintained for services only, and the other main not allowed to be tapped for services, is there any credit allowed?

Mr. Caldwell. That will show up in the fire-flow tests. If we had a situation like that we would give credit by conducting a test on the main that did not have the service connections.

Mr. S. H. Taylor.† I should like to call attention to a case where a penalty was imposed for a hydrant on a dead end. In the outlying districts we laid pipes to supply one or two houses and put a hydrant on the end. Now, if a waste gate were placed there, and no hydrant, the penalty would be eliminated.

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* Superintendent, Water Works, Springfield, Mass.

† Assistant Superintendent, Water Works, New Bedford, Mass.

Mr. Caldwell. I think we all know where Mr. Taylor comes from, and as his system has only thirty-odd points deficiency I think you must agree that we are not very severe on him for his hydrants on dead ends.

Mr. William F. Sullivan.* Would you penalize a city that had 4-in. pipes, and had those 4-in. pipes reinforced with a gridiron so that it gave a fire flow?

Mr. Caldwell. I think you have assumed almost an impossible condition there. It would be almost impracticable to so reinforce a system of 4-in. pipes. But still, if such a system would furnish the required fire flow we would be obliged to give it credit.

Mr. J. H. Howland.† I should like by way of explanation to supplement Mr. Caldwell's answer to Mr. King's question. There might be an impression that making a charge for two pumps out of service was rather excessive. Perhaps a good many of you remember an experience that was had at Little Rock, Ark., about five or six years ago. They had three pumps in service. The largest pump, I think, broke the cylinder head, and in order to keep up with a very high rate of consumption the second largest pump was speeded up. That broke down, and then the last pump broke down, exhausted the reservoir on the hill; but they shut off that reservoir with about two feet of water in it, leaving the town without any water supply. So that while the charge, as Mr. Caldwell has explained, is a big one when there was but one pump out of service, I think we are justified in making a charge in case of two pumps being out of service. It is quite liable. It has happened not only in Little Rock but in other cities.

There is one matter that I have often wondered whether we were unduly disturbed about, and that is the introducing of a charge for unreliability where pressures in mains exceeded double or were equal to double their designed working pressure. Springfield, in abandoning the Ludlow system, where I think they had a pressure of about 85 lb. in the congested districts, brought in the Little River supply with 140 lb. in the business district, and I think that our engineer in Springfield will tell you that there are a number of places where he has got 43-lb. pipe withstanding that pressure to-day. Syracuse, N. Y., if I remember rightly, practically doubled her pressures when they brought in a new reservoir on higher pressure, bringing the pressures from somewhere in the neighborhood of 40 lb. up to approximately 90 lb.; and in Syracuse you will find a pretty liberal per cent. of 43-lb. pipe. I know this matter has been discussed at the National Board conferences, and we think we are justified in charging for pipe that is withstanding double its working pressure.

Mr. George Cassell.‡ If a building has a 6-in. connection going into it from a 12-in. main, with 100 lb. to the square inch, and the owner of that building should desire to have another 6-in. taken off that same

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† Engineer, National Board of Fire Underwriters.

‡ Water Commissioner, Chelsea, Mass.

main, into that same building, for a sprinkler service, would it be advisable to do so, in your opinion?

Mr. Caldwell. Of course that would depend somewhat on local conditions. The size of that pipe would be determined by the construction, the area, and the occupancy of the building in question. I am heartily in sympathy with this idea of the water-works people, against installing too many large-sized sprinkler connections; still, at the same time you do not want to go the other way. Now, we have a whole lot of cases where we do not think we should be limited to a 4-in. connection where the area or occupancy is considered, and the number of sprinklers supplied distinctly requires more than what the 4-in. pipe would deliver. So I am afraid I cannot answer that question definitely, but I can appreciate the fact that in some cases it would be undesirable, from the water-works point of view, to permit two 6-in. parallel connections right off a 12-in. main.

Mr. Cassell. It seems to me from my experience that if a 6-in. pipe, with 100-lb. pressure, will take care of 200 sprinklers, and they say there shouldn't be any more, there must be some pressure left behind.

Mr. Caldwell. Yes, there is.

Mr. Cassell. So that it would naturally supply an adequate amount of water for 200 sprinklers. Now, if that is the fact, why is there any necessity of having any more, unless to provide against accident to that particular line?

Mr. Caldwell. We never bring in duplicate lines for that purpose; but, if the requirements call for more than 200 sprinklers, then either an additional 6 in. or 8 in. must be installed; that does not mean necessarily from the street. It might be brought in from the yard system, if the plant was a large one and they had a private pipe system of their own.

Mr. Cassell. Don't you think it is much better under those conditions to supply two 4's instead of one 6, so that in case one line breaks the other line will be in operation?

Mr. Caldwell. Under the item of reliability you are absolutely right; on the item of adequacy you are not. There is not the carrying capacity in two 4's that there is in one 6-in.

Mr. Cassell. Which, in your opinion, would be preferable, a 6-in. or two 4's?

Mr. Caldwell. My answer to that would be determined entirely by the nature of the building and the occupancy that I was attempting to protect. If I had a building which was readily ignitable, or I had an occupancy that was liable to produce a flash fire, give me the 6-in. connection; give me all the water just as quickly as you can get it. But if I had the ordinary occupancy and slow-burning construction, I am not so sure but what I would lean to the two 4-in. connections.

Mr. Cassell. I might agree with you. Now, if a 6-in. sprinkler system is connected with a high-service main that furnishes water to the higher elevations in a city, and the water pressure at the highest point is

40 lb. and at the lowest is 100 lb., and a break should occur in the 6-in. sprinkler service and the discharge of water from it reduces the pressure so that no water would be available for the properties on the higher elevations, are we not jeopardizing the lives and the property of the people there?

Mr. Caldwell. That is true.

Mr. Cassell. Then, Mr. Caldwell, it seems to me that it is very unwise to take such a chance as that, because the only difference I can distinguish between the two is this, — that one reduces the premiums and the other jeopardizes the lives and property of the other people.

Mr. Caldwell. Do you think experience has shown that?

Mr. Cassell. No; but, as somebody said, a minute ago, the inevitable always happens. It happened in my city in 1908.

While I and every water-works man who belongs to the Association wants to coöperate and do everything that is possible to create a high standard of efficiency for fire purposes, and to coöperate with the insurance companies, I think and feel that the insurance companies are crowding us a little bit when they are trying to force us to give these things that are really beyond the possibility of giving, without jeopardizing the lives and property of people in other sections of the city.

Mr. Caldwell. I think you are right. There is something to be said for and against both sides there. And I think in a great many cases undoubtedly the men who have laid out sprinkler equipments for different insurance organizations have not used good judgment as to calling for certain-sized connections. In fact, there have been numerous cases come to my knowledge where men have asked for connections from street mains where the street mains were not capable of supplying the capacity of pipe that they were asking to be installed.

Mr. Cassell. I wish to give the property owner everything I possibly can, and, if possible, to satisfy the insurance people. I think that so far as my city is concerned we have done so. The one mistake we made in that line was to give a 6-in. supply, because our capacities are not very large, as you know, although we are very well fixed.

President Macksey. When the underwriters lay out a sprinkler outfit for a plant, and try to provide a supply for it, do they call for a supply that will cover all sprinkler heads in the plant open at one time?

Mr. Caldwell. No, they do not, Mr. President. The size of the supply is dependent upon the number of sprinklers in a given floor area. In other words, we might have a building 200 ft. long, 50 ft. wide, and four stories high. Now, we couldn't call for a supply which would take care of the total area of that building for all four floors, but we assume only one floor at a time. In other words, we would lay out the necessary sprinklers for an area 200 by 50 ft., for one floor; — the size of supply main in that building would be designed to take care of that one floor alone.

President Macksey. In other words, the probability of two or three fires coming at one time is not as great as the probability of two or three pumps breaking down at one time, and therefore is not provided for.

Mr. Sullivan. Regarding the financial phase of this problem. How are the water works, without funds, going to fix up their systems, maintain operation, and keep it up so that they won't be penalized, and get this 1 700 points? I cannot see where we are going to get all these improvements done without money; and as competent managers of water works you have got to conserve the money you have. You cannot replace all the 4-in., 6-in., and 8-in. pipe with pipe of diameters large enough to ensure in every part of the city or town a sufficient fire flow. There is no city or town that wants the weak spots. I do not recall that Mr. Caldwell is interested in the financial end of the question. But it is a question to-day. I do not know of any water departments, or companies, that are paying 100 per cent. at any time; but I do know of some insurance companies that have — though I did not bring that up as a matter of discussion. [Laughter.]

Mr. Patrick Gear.* I never knew in this country of any system that was up to the standard that is required by the insurance companies. We had them in Holyoke, grading us in 1915. They gave us a penalty of 156, but we got back at them, and got off 22 or 23 points.

Now, they penalized us for 4-in. hydrants, but I do not agree with them, for there is a place in the small city or town for the 4-in. hydrant, even with one nozzle.

Mr. H. C. Crowell.† Mr. Caldwell, do not some cities restrict their fire service connections to 4-in.?

Mr. Caldwell. Yes, I think they do, Mr. Crowell. We do not have jurisdiction in Boston, but I think I am correct in saying that they will permit only 4-in. sprinkler services. They will permit more than one, if the area of the building demands more than what the 4-in. will supply. Didn't you follow that practice out in Woburn, Mr. Macksey?

President Macksey. Yes, we made a 4-in. rule in Woburn. In the town, where small pipes had to supply a number of people, we believe, as does Mr. Cassell, that we ought to look after the interest of the whole and pay very little attention to the individual problem.

Mr. Crowell. What would be the result in Haverhill if they restricted their fire services to 4-in.? A great many of the mains are small. We have both high and low pressure there.

Mr. Caldwell. You do not mean by that to replace any existing 6-in.?

Mr. Crowell. Well, I referred to new ones; but of course personally I believe that the fire services are too large, considering the size of the mains.

Mr. Caldwell. That would be a point that would not come under my jurisdiction; but my thought on that matter would be that in those cases where the 4-in. supply would meet the area occupancy and con-

* Superintendent of Water Works, Holyoke, Mass.

† Superintendent of Water Works, Haverhill, Mass.

struction conditions I don't see why they should make any difference in rate. It is a problem that has been discussed for years, and there is something to be said on both sides of it; but it does seem to me that the interests of the water companies and the insurance interests certainly are mutual. We are after the best protection possible to safeguard the owner of the property and the integrity of the water system. I realize that in numerous cases undoubtedly there have been what you would call layouts made for individual sprinkler equipments, which would be open to some criticisms, but I don't think you should blame the system so much as you should blame the individual who laid out that system. But I do believe there is such a thing as getting together on this thing and accomplishing or at least working out a plan which would be satisfactory both to the water interests and the insurance interests.

Mr. Crowell. In Haverhill quite a lot of the mains are too small. The National Board of Insurance Underwriters have been in Haverhill several times, and I think that they want to do all that they can to help out every city.

Mr. McInnes. Why shouldn't the Standard Schedule penalize unduly large connections from the mains of a distribution system for fire or other purposes? Such connections exist and constitute serious danger spots which should logically appear as points of deficiency in the Schedule.

Mr. Howland. Is there any member of this Association present who knows of one instance in the country where 6-in. or larger connections of sprinkler systems have seriously depleted the water supply?

A Member. Jacksonville.

Mr. Richard D. Chase.* Some years ago I had occasion to look this thing up and collected quite a number of instances where most serious difficulty had occurred with large connections collapsing, reducing the pressure. In Rochester, N. Y., there was an 8-in. connection to a large brick building, the use of which collapsed it. The chief of the fire department came to the superintendent or engineer of the water board and told him that they were not getting any water; the superintendent, pointing to a big pile of brick in the street, said, "Until you get this pile of brick off I cannot close that gate." It seems to me the Salem fire was pretty closely connected with a couple of large sprinkler connections that were destroyed. I firmly believe these are a serious menace to any distribution system.

Mr. Sullivan. I believe in the Journal of the Water Works Association the gentlemen will find an unusually well-written paper on this subject by Messrs. McInnes and Goldsmith, in regard to the Salem fire.

* New Bedford, Mass.

GENEVA.

Introduction to Monsieur Bétant's Paper.

PROF. GEORGE C. WHIPPLE.*

[*Read December 8, 1920.*]

In view of the fact that you are to listen to a paper describing the water supply of Geneva, by Monsieur A. Bétant, engineer of the water service of that city, and also that Geneva has been selected as the headquarters of the League of Nations, it may not be inappropriate for me to tell you in a few words what kind of a place Geneva is. I resided there for eight months, — that is, from February to September, 1920.

Geneva is situated in the extreme southerly part of Switzerland, and is almost completely surrounded by France. Consequently it is essentially a French-speaking city. At the census of 1910, 70 per cent. of the people spoke French, 12 per cent. German, and 9 per cent. Italian. In 1910 the population was 123 153. In 1919 it was estimated to be 141 000, being the third largest city in Switzerland. Zürich and Bâle (Basel) are larger than it, but Bern, the capital, is slightly smaller.

Geneva is situated at the foot of Lake Geneva (Lac Leman), which is an expansion of the River Rhone, about 50 miles long and 10 miles wide. The Rhone River rises in the north, near the St. Gothard Pass, and is a muddy glacial stream, especially in the summer when the glaciers are melting. The turbidity settles out in the lake to a considerable extent. At Lausanne, which is half way down the lake, the water is not suitable for public supply, and this city has extended its aqueduct far to the north in order to obtain water from the mountains. The sewage of Lausanne empties into the lake. At Geneva the water is usually beautifully clear and of a bright blue color, but at times it shows the presence of colloidal matter. During periods of high wind, and especially when there is a "*bise*" blowing down the lake, the water becomes greenish in the middle and brownish near the shores. Such analyses as have been made indicate that the water is probably safe for drinking; but in view of the pollution which the lake receives at various places it cannot be asserted that the final word has been said on this point. Just above the outlet of the lake there are two jetties which extend into the water, forming a sort of basin which in many respects reminds one of the Charles River Basin in Boston, especially at night when the shores are fringed with rows of electric lights. The current becomes quite swift as the water enters the Rhone River. Just below the

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* Professor of Sanitary Engineering, Harvard Engineering School.

outlet is the power plant described by M. Bétant in his paper. A few miles farther down stream there is a hydro-electric plant, also mentioned in his paper. The sewage of the city is discharged untreated into the Rhone, but there is a very great dilution.

Historically, Geneva is one of the most interesting cities of the world. It was a thriving place when Cæsar made his conquest of Gaul. Some of the old Roman walls are still standing, and the site of the bridge which connected the land of the Helvetians with the land of the Allobroges is still occupied by an important bridge crossing the Rhone. Geneva as a city has led a sort of independent life, and, according to the fortunes of war, has been under various authorities, the stories of the early wars being full of interest and excitement. Geneva was the home of John Calvin, and the Calvinistic influence on the city has been very great. It was one of the early seats of Protestantism, but at the present time the population is about equally divided between Catholics and Protestants. The city centers around the St. Pierre Cathedral, which dates from the tenth century. Calvin preached in this church, and near it stands the high school which he built in the fifteenth century and to which all of the Genevan boys go. There are some notable statues of Calvin and other leaders of the Reformation, including Oliver Cromwell and Roger Williams, in the park which surrounds the university. Geneva has always been a city of refuge for persecuted peoples, and this to some extent accounts for its large French population. More than almost any city with which I am acquainted Geneva treasures its educational and spiritual traditions.

The City Hall in Geneva is a very fine example of old architecture. It contains several famous rooms. The Salle d'Alabama is the room in which the Red Cross movement first took shape in 1863, and where in 1872 the Alabama Claims between the United States and Great Britain were adjusted. The Council Chamber was the seat of the first International Red Cross Convention, in 1864. Both of these rooms were recently used in connection with the first conference of the League of Red Cross Societies in March, 1920.

Geneva is fast getting to be an international city. Many conventions in recent years have met there. It has for many years been the headquarters of the International Red Cross Committee. It is now the headquarters of the League of Red Cross Societies, and quite recently the League of Nations has purchased one of the largest hotels on the shore of the lake as the headquarters of its secretariat. It is expected that, little by little, other international bodies will locate there until this city becomes what the Genevans are already beginning to call it, "the capital of the world."

Geneva is in many ways fitted to be such a capital. Traditionally it has an independence not found in other European cities. It is a neutral city in a neutral country, removed from the ordinary lines of commerce and manufacturing. It is a comfortable place to live in, has fine buildings, good hotels, clean streets, and in general is a well-organized municipality.

It is surrounded by inspiring mountains, the Juras on one side and the Alps on the other. It is an intellectual center, the seat of a great university and of many schools. Geneva has never taken pride in its growth. Naturally, some of the commercial interests have endeavored to boom the place for business reasons, but, so far as the old residents of Geneva are concerned, they do not take pride in the increase of population. In fact, they are somewhat inclined to resent the intrusion of so many people from outside. They have not liked to see the numbers of automobiles increase, and they have made strict laws in regard to their " circulation," especially on Sunday. They enjoy the peace and quiet of their beautiful little city. Nevertheless they are proud of seeing it assume such an important place in the world.

Monsieur A. Bétant, the engineer of the water service of Geneva, is a typical water-works man, and would fit in very well with the members of this Association. I am sure that we all welcome M. Bétant as a contributor to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION. He takes a keen interest in the quality of the Geneva water, and has for a long time kept up regular quantitative tests of the plankton, — that is, the microscopic organisms. On visiting his office, one day, I was surprised to find on his shelves a copy of the latest edition of my own book on " The Microscopy of Drinking Water." This leads me to make mention of the admirable pioneer limnological work carried on by Dr. Forel at Lausanne more than thirty years ago. A physician by profession, he studied Lake Geneva in all its aspects for many years, and the result was a three-volume book in French, known as " Le Leman," the first great work on limnology. This was one of the first books on this subject which I ever studied and one which I used a great deal in connection with the biological work at the Chestnut Hill Reservoir during the years 1889 to 1897. Last summer I took peculiar pleasure in presenting to the library of the University of Lausanne a copy of my book, in which I had inscribed a few words of appreciation of Dr. Forel's work, and the influence which it has had on the development of limnology in America.

THE WATER SUPPLY OF GENEVA, SWITZERLAND.*

BY MONSIEUR A. BÉTANT.†

[*Read by Prof. George C. Whipple, December 8, 1920.*]

The city of Geneva, as well as the greater part of the *canton* of the same name, comprising in all a population of about 148 000, is supplied with unfiltered water from Lake Geneva. The water is pumped by hydraulic turbines which have a capacity of 3 000 h.p., the necessary driving force being supplied by the Rhone River at Coulouvrenière, near the outlet of Lake Geneva.

The distributing system extends over a radius of 15 km. (9.3 miles) from the pumping station. The quantity of water pumped in 1919 was 46 654 757 cu. m. (12 310 million gallons), of which 24 146 233 cu. m. (6 370 million gallons) was used for household purposes and 22 508 524 cu. m. (5 940 million gallons) for power purposes, the average domestic consumption being 447 liters (118 gal.) per capita daily. The average daily consumption was about 34 million gallons, of which 17.5 was for household purposes.

Pumping Machinery.

The pumping machinery consists of 18 Jonval turbines with vertical axis designed for falls of 1.8 to 4 m. (5.9 to 13.1 ft.). Each turbine directly engages a double Girard pump equipped with piston plungers. The two parts of this pump are placed at right angles to one another and form independent groups of 250 h.p. capacity.

The heads on the pumps correspond to those of the distributing systems. Three low-pressure pumps raise the water about 60 m. (196 ft.) and serve the lower parts of the city; five high-pressure pumps raise the water for the domestic supply of the *canton* 140 m. (457 ft.); and ten high-pressure pumps raise the water for power purposes throughout the city 135 m. (441 ft.).

Three centrifugal pumps operated by electric motors, one of 1 000 and the others of 500 h.p. capacity, are kept in reserve. Electric current is supplied to the motors by the power plant at Chèvres, lower down on the Rhone River. The reserve units are employed when the height of water in the river is not sufficient to give the turbines their normal head of water, a circumstance that necessitates the use of a different source of power.

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* Translated by George C. Whipple and Gordon M. Fair.

† Engineer and Director of Water Supply Service, City of Geneva.

Water for Domestic Supply.

The water used for household purposes is taken from the lake and is not filtered. After flowing across Lake Geneva, which serves as a very large natural sedimentation basin, the lake water contains no pathogenic bacteria and can be obtained pure from an intake situated at a sufficient depth and at a distance from the shores great enough to avoid accidental contamination from local sources.

The Geneva intake opening is at a depth of about 15 m. (49 ft.) and at a distance of 2.5 km. (1.55 miles) from the harbor jetties and 1.3 km. (0.81 miles) from the lake shore. The water runs to the pumping station at Coulouvrenière through a pipe 1.2 m. (48 in.) in diameter and 3 660 m. (12 000 ft.) long. The conduit is laid on the bottom of the lake and Rhone River. (See Fig 1.)

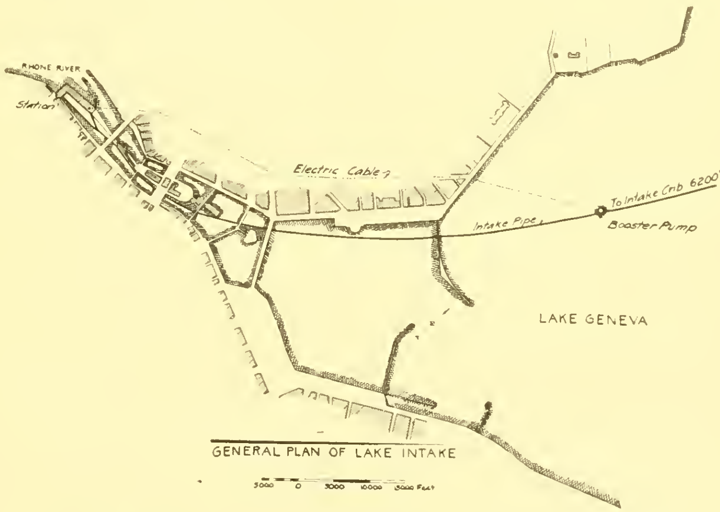

Fig. 1. Map showing the Location of Intake Pipe, Pumping Station and Booster Pump.

(Pumping Station at " Station," upper left-hand corner.)

Up to a few years ago the water flowed by gravity to the pumping station, because of the difference in level between the lake surface and the pump suction. The conduit then had a capacity of 600 to 800 liters per second (13.7 to 18.3 million gallons a day). In 1913, however, it became necessary in consequence of the steady increase in water consumption to enlarge the capacity of the conduit to 1 100 liters per second (25.2 million gallons per day). This was accomplished by installing an electrically-operated centrifugal pump in the line of the conduit. The pump site was located in the lake at a point 600 m. (1 970 ft.) from the jetty, in order to place under pressure the section of the conduit that passed under the harbor of the city. If, thereafter, one of the pipe joints should leak, the flow

would be outward and the water in the conduit would be protected against pollution.

For the purpose of connecting the pump to the intake, a sheet-iron caisson 7 m. (23 ft.) in diameter at the base was floated to the pump site and sunk by being filled with concrete. The caisson, resting in 4 m. (13.1 ft.) of water on the level bottom of the lake, was then secured by 16 anchor piles placed around its circumference, and the pump and motor were

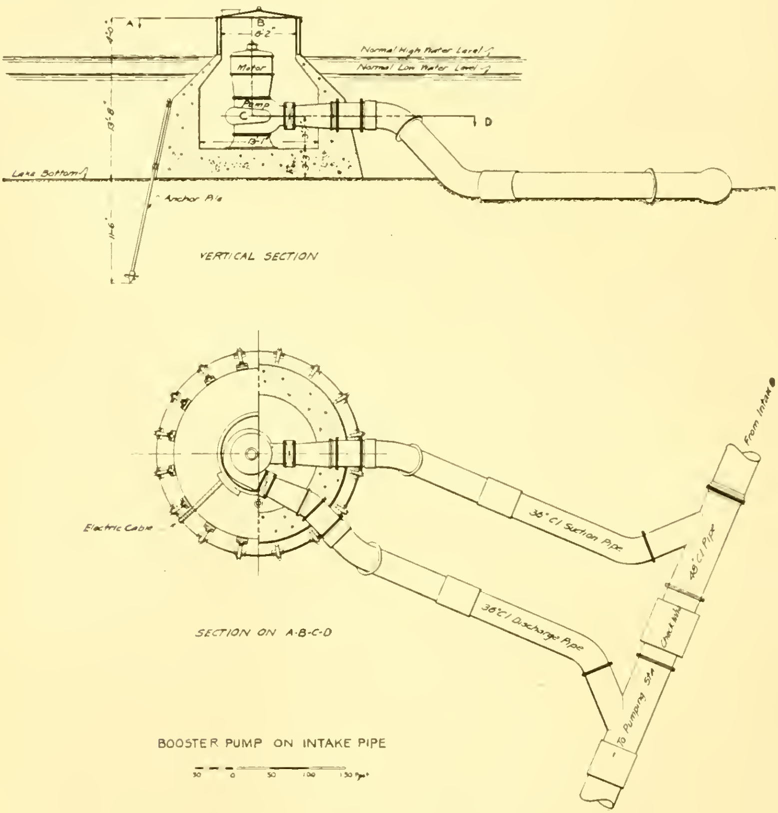

Fig. 2. Sketch of Booster Pump on Intake Pipe.

mounted in the central cavity that had been provided in the caisson when it was filled with concrete. The vertical pump shaft is direct-connected to the motor which is mounted in the same frame. The pump is designed for a lift of 3 m. (9.8 ft.) and has a capacity of 66 cu. m. per minute (25.2 million gallons per day). It operates at a rate of 200 revolutions per minute and is driven by a 65 h.p. motor running on 3-phase alternating current. The electricity is provided by a special generator, operated by a high-pressure turbine at the Coulouvrenière station. An independent cable connects the two machines in short circuit, so that the whole installation can be operated from the pumping station.

After sinking the caisson, a 10 m. (32.8 ft.) section of the conduit was replaced by two special castings with side outlets, a check valve being inserted between them to permit the pressure to adjust itself automatically when the pump was started. The two side outlets were connected to the suction and the discharge of the pump by pipe-castings passing through the walls of the caisson.

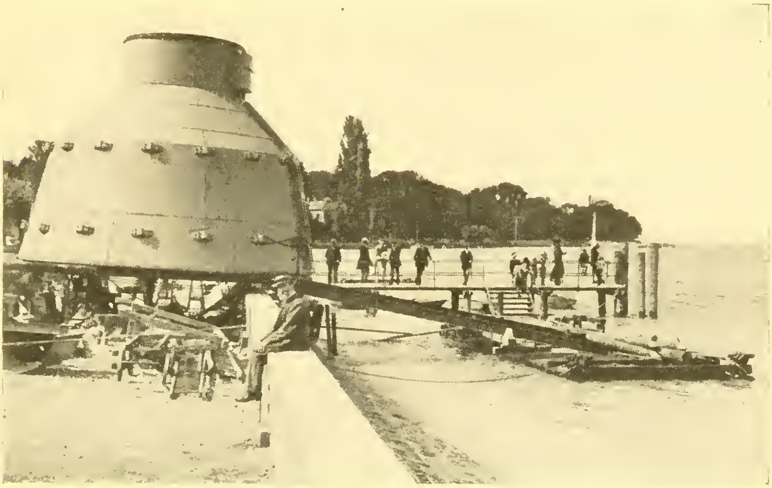

Fig. 3. Sheet-Iron Caisson on Shore, ready to be Launched.

Fig. 4. Caisson in Place, showing Supporting Piles.

The installation was placed in service in June, 1914, and has since been in regular operation. As previously stated, it is controlled from Coulouvrenière, an arrangement which makes it unnecessary to visit the caisson oftener than once a month, when pump and motor are oiled.

Distributing Systems.

There are three distributing systems, the total length of pipes amounting to 471 km. (293 miles). Each system has an independent reservoir. That of the low-pressure system, providing the domestic supply for the lower part of the city, is situated at Bois de la Bâtie and has a capacity of 4 800 cu. m. (1.2 million gallons). The high-pressure reservoir supplying drinking water to the *canton* is at Bernex and holds 3 000 cu. m. (0.8 million gallons). The distributing system that provides hydraulic power for motors, elevators, vacuum cleaners, and other machinery, has its reservoir at Bessinge. As a constant pressure is necessary for this power service, the pressure at the lower end of the conduit leading to the reservoir is regulated by a centrifugal pump run by a 100 h.p. motor. The pump is placed in service during the day and increases the pressure by an amount equal to twice the loss of head in the conduit; this establishes equality between the day service (water level in the reservoir falling) and the night service (water level in the reservoir rising).

Certain distant parts of the *canton* too high in elevation to be reached by the general distributing system are supplied by small booster pumps, operated by electric motors of 5 or 6 h.p. rating, that take water from the general distributing system and pump it into secondary systems with reservoirs at some commanding place.

There are three of these secondary services, each with a booster station and a reservoir of 200 cu. m. (53 000 gal.) capacity. Two of these reservoirs, at Landecy and at Jussy, are water towers; the third is a standpipe on a hill at Choully.

The distributing system, therefore, has in all seven reservoirs:

Principal Reservoirs.

La Bâtie.....	4 800 cu. m.	(1 200 000 gal.)	Domestic service.
Bernex......	3 000 cu. m.	(800 000 gal.)	Domestic service.
Bessinge.....	12 500 cu. m.	(3 300 000 gal.)	Power service.

Auxiliary Reservoirs.

For Domestic Supply of the *Canton*.

Chancy......	200 cu. m.	(53 000 gal.)	
Choully......	200 cu. m.	(53 000 gal.)	with booster pump at Satigny.
Landecy.....	200 cu. m.	(53 000 gal.)	with booster pump at Perly.
Jussy........	200 cu. m.	(53 000 gal.)	with booster pump at Eaux-Vives.

Rates and Regulations.

The water rates of the city of Geneva are based upon the measurement of water by meter and pressure-gage. Meter rates are applied at present to nearly all connections; in some cases they are obligatory. The pressure-gage system was used at a time when the pumps were less powerful and the reservoirs of insufficient capacity. It was then a matter of importance to

operate the distributing system uniformly without sudden changes in pressure.

The gage-cock was placed under the sidewalk of the property served, and permitted the continual passage of a certain measured quantity of water. The consumer accumulated the water in a reservoir and used it according to his needs. The unit-measure of discharge was the "liter per minute." The consumer paid a price per year varying with the number of

Fig. 5. Motor ready to be Lowered into the Caisson.

"liters per minute" received. This price was 48 francs for the low-pressure system in the city and 60 francs for the high-pressure system outside the city, corresponding to $36.30 and $45.40 per year for each "gallon per minute," if the Swiss *franc* is given a normal equivalent of 20 cents.

After the pumping equipment had been increased and new reservoirs had been constructed, it became possible to sell water everywhere by meter measurement. This was done especially in the *communes* (sections of the

canton) most distant from the pumps. The meter measurement system is now the only one used for new connections. It has the advantage of enabling the consumer to draw at any time the largest quantity of water required, an arrangement which does away with the use of tanks which caused stagnation and uncleanliness.

It is usually admitted that meter rates for the minimum yearly consumption should yield amounts sufficiently large to pay for the connection

FIG. 6. BOOSTER STATION COMPLETED.

and the general service expense. The minimum rate of consumption may be 300, 400, 800, 1 200, or 2 000 cu. m. per year for domestic services (79 000, 105 000, 211 000, 317 000, or 528 000 gal. per year). For small properties not exceeding 10 000 *francs* ($2 000) in value, however, the schedule fixes a minimum rate as low as 150 cu. m. (39 000 gal.) per year. The minimum charge is payable at the beginning of the year. The actual consumption is determined at the end of this time, and the consumer is charged for whatever the quantity in excess may be.

Contrary to the usual practice of cities in which the distribution of water has been made a business proposition, the minimum annual charge at Geneva is not fixed by the city. The consumer instead is given the privilege of choosing his minimum rate from the above-mentioned series. The prices per cubic meter follow a sliding scale, varying from 18 to 11 *centimes* per cu. m. (13.6 to 8.3 cents per 1 000 gal.), according to the limit of the minimum quantity. The consumer therefore finds it to his advantage to pay at the beginning of the year the price of the minimum rate most nearly approaching his actual consumption. For example, a consumer who uses 1 275 cu. m. during the year saves 27 *francs* ($5.40) by paying a minimum charge for 1 200 cu. m. at 13 *centimes* (8.25 *francs*), a total of 164.25 *francs*, instead of paying a minimum of 300 cu. m. at 15 *centimes* (45 *francs*) and an excess charge for 975 cu. m. at 15 *centimes* (146.25 *francs*), a total of 191.25 *francs*. The administration hereby secures the advantage of obtaining larger receipts at the beginning of the year, and the consumer profits by the lower rate. Meters are furnished without charge to domestic consumers.

In the water-power service which runs motors, elevators, vacuum cleaners, and other machinery, the charge for motors is made either by lump sum or by meter measurement. In the first instance, the price is fixed according to the number of brake horse-power furnished, and varies with the pressure from 400 to 140 *francs* ($20 to $7). In the second instance, the water is measured and the price varies from 7 to 3 *centimes* per cu. m. (5.3 to 2.3 cents per 1 000 gal.), with a minimum charge depending upon the pressure supplied. For elevators and vacuum cleaners, the water is also sold by meter, the minimum annual charge for this type of machinery being 100 *francs* ($20).

Tables showing the chemical and bacteriological analyses of Geneva water are appended. These were kindly furnished by Professor Christiani of the University of Geneva and chief of the Department of Hygiene of the canton of Geneva.

TABLE 1.

Average Chemical Analysis of the Geneva Water Supply.

	Parts per Million.
Total residue (100° C.)	170–185
Mineral residue (180° C.)	160
Carbonates	90
Alkalinity	9
Total hardness	16
Temporary hardness	9
Permanent hardness	7
Oxygen consumed	2.2
Ammonia	Absent
Nitrites	Absent
Nitrates	Absent
Chlorides	2

TABLE 2.

Summary of Bacteriological Analyses of the Geneva Water Supply. 1911—1919.

	Bacteria per C.C. Minimum.	Average.	Maximum.	B. Coli in 10 C.C.
1911	15	106	221	0
1912	43	155	1 242	0
1913	21	89	153	0
1914	26	110	285	0
1915	11	95	440	0
1916	20	76	140	0
1917	10	82	302	0
1918	20	55	153	0
1919	29	180	568	0

Discussion.

Mr. Samuel E. Killam.* Can you give us the yield per square mile of the watershed of that lake?

Professor Whipple. No, I cannot. The lake is about 50 miles long and 10 miles wide. The watershed is not very wide near Geneva, but it has the range of the whole Rhone River, which is a very large area.

Mr. Killam. Also the width of the dam at the end of the lake — do you know that?

Professor Whipple. Six hundred or eight hundred feet, perhaps.

* Superintendent, Metropolitan Water Works.

AIR IN GRAVITY MAINS.

J. W. LEDOUX.*

[*November 10, 1920.*]

Nearly every water-works superintendent has experienced trouble in connection with some phase of air in pipes. A leaky suction pipe often reduces the plant efficiency materially, and sometimes results in serious damage to the pumping machinery.

Where the discharge pipe is perfectly tight, if a small quantity of air be pumped with the water it is likely to accumulate on the summits and appreciably reduce the capacity of the pumping main, or, what is the same thing, increase the frictional head due to the reduced cross-section of the pipe at the summits. The remedy is to prevent the ingress of air at the pumping plant; but even at best more or less air is entrained with the water, and under reduced pressure at the summits this air may at times accumulate, and then the only remedy is to provide on these summits automatic air valves. However, this difficulty is not common, for several reasons. Unless it enters the pumping main in large quantities it is generally carried along with the water, and if an air obstruction develops the automatically increased pumping pressure tends to drive it over the summits by attrition. Also, air will escape through apertures too small to show water leaks, and there are usually enough of these to prevent noticeable trouble from pumping discharge mains. This property of air is often the cause of leaks, for in discharging at a high velocity it increases the size of the aperture by washing out fine particles of material that would remain in place if the pipe were full of water.

While the cushioning effect of air in mains often prevents serious water hammer, on the other hand its sudden escape at a high velocity, as sometimes happens, will produce serious water hammer.

The accumulation of air in summits of gravity mains has frequently resulted in the complete interruption of the supply on large portions of the system; and sometimes this phenomenon is troublesome and difficult of correction.

In one case in the experience of the writer a 14-in. main extended from a distributing reservoir, at elevation 628, across a valley the elevation of which was 150, to the opposite hill at elevation 550, where there was a considerable amount of population and very variable topography. Branches from this main extended at right angles in both directions to lower elevations. It was found that no water could be furnished on one of these branches, as was evidenced by the complaints of the consumers. The spigots were opened in houses, and the water would not flow even at

* Consulting Engineer, Philadelphia, Pa.

the ground floor. After many hours' investigation, a pocket of air under pressure was discovered at one of the summits, and as soon as this was released the supply was immediately resumed.

Another case consisted of a 16-in. gravity main from an impounding reservoir eight miles to two standpipes supplying the railroad service. It was found, one afternoon, that no water would flow into the standpipes, and it was immediately assumed that somebody had closed a valve or that the reservoir was empty, because there had not been experienced any trouble since the line was installed several months previously. An inspection was made; air valves were opened all along the mountain at the various summits; no water flowed and no air came out of the main. It was finally learned that, on the day before, a valve had been closed near the reservoir to make some slight repair on the line; on inquiry it was found that this valve had been reopened, and this was verified. It had been the intention to locate automatic air valves at all the summits. One of these summits was close to the impounding reservoir. Finally, this air valve was examined and to the surprise of every one it was found disconnected and lying in the valve pit. On opening the air valve connection the air escaped and the water began to flow freely. This particular summit was so close to the reservoir and so small as compared with the others on the line that no one suspected that trouble existed at that point.

The following diagram, Fig. 1, illustrates the principle.

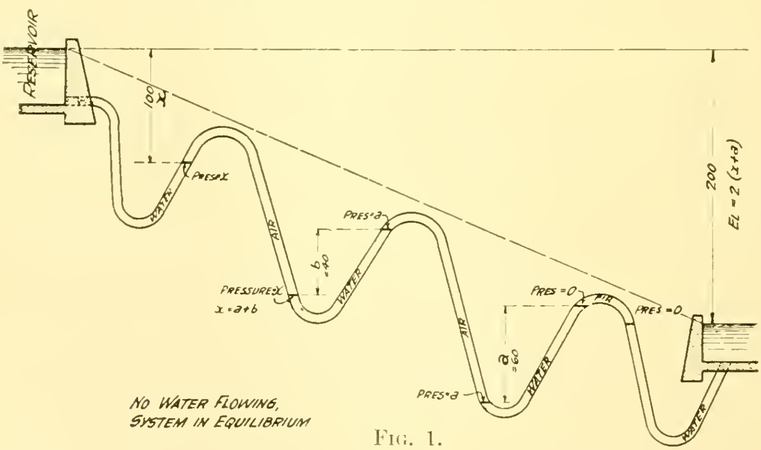

Fig. 1.

In this case the impounding reservoir is shown 200 ft. above the distributing reservoir, and under these conditions no water can flow through the line until the air is relieved at the summits.

Figure 2 illustrates about the conditions that occurred in the gravity supply to the railroad tanks.

The above examples show conditions of static equilibrium and a balance which is frequently very delicate. This condition is not likely to take place with pumping mains, where the pressures fluctuate, but is character-

istic of fixed levels of water as occur in gravity mains. At least, that has been the experience of the writer.

One of the most important conditions where serious damage can be caused on a pipe line is in the case of a large wood or steel pipe laid over summits and valleys. If, due to water hammer or defect in the pipe, an actual split or break of the pipe takes place in the valley, permitting a large quantity of water to discharge faster than the water can pass over the summit to keep the pipe full, a partial vacuum occurs, and unless the pipe

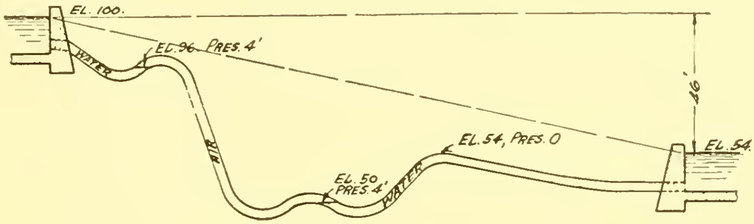

Fig. 2.

is designed to resist it, collapse will take place. The only remedy for this danger is to maintain a sufficient number of poppet valves designed to take large quantities of air into the line automatically; some very serious damage has taken place, due to the absence or insufficient size of these automatic poppet valves.

A vacuum is sometimes caused in a pipe line for another reason: Let us suppose a large wood or steel pipe line extends from a distributing reservoir down the hillside to a flat 200 ft. below, and that the pipe line is full of water but not flowing. Now, if between the base of the hill and the distributing reservoir a valve be shut, the pressure at the downstream side of the valve will at once drop to almost a complete vacuum, because this part of the pipe line is relieved of the atmospheric pressure acting on the distributing reservoir. Under these conditions collapse of the pipe is likely to take place.

In connection with this subject, it may be well to call attention to the best method of filling a gravity piping system that has been for some cause emptied. The writer has heard many experienced water-works men advocate filling the pipe line by sections. This is a very bad practice. The best method is to open air valves at all the summits, and open the blow-off valves in all the hollows and a sufficient number of hydrants in the town. Then the valve at the impounding reservoir is opened a sufficient amount to fill the line in a predetermined time. As soon as the water appears at the first blow-off and flows full, this is shut, and as soon as it flows full at the second blow-off, that is also shut, and so on, until the water appears at the city hydrants, shutting the low ones first and following them up until the high ones are shut; finally, the air valves on the line are closed and the line is in service, and no danger of water hammer has been experienced, and the line is filled in a shorter time than can be done by any other method.

WASTE RESTRICTION IN BOSTON.

FRANK A. MC INNES.*

[*Read November 10, 1920.*]

The following is the story of a small skirmish in the everlasting war against waste which is the heritage of every good water-works man:

In 1919 the daily average consumption of Boston was 89 652 400 gals. and the daily per capita 111 gals. A subdivision of the total consumption, made possible by the manner in which the supply is measured, pointed to the Charlestown District as probably a great offender from the point of view of waste. This district has a population of approximately 34 500, a pipe mileage of 31.9 and an unusually large industrial consumption. It is very thickly settled and entirely metered.

A contract for a waste survey was made with the Pitometer Co. of New York, the work to include a test of the Venturi meters measuring the flow into the district; a division of the district into sections and a measurement of the flow into each section; a detailed investigation in all sections where excessive waste is indicated and the location of actual leaks; a check on all large consumers for the purpose of determining unauthorized use of water, and a test of all fire pipes and meters larger than 3-in. The survey was begun May 10, 1920, and completed July 30, 1920.

The result of the work was a saving of 955 000 gals. in a week-day average daily consumption of 6 582 540 gals.,— a little more than 14 per cent. The leaks located and stopped were as follows:

	Amount of Waste.	Outlet.
Broken 3-in. pipe,	253 000 gals. per day	Following wall to river.
Blown 8-in. joint,	149 000 gals. per day	Underground to river.
Broken $\frac{5}{8}$-in. service,	121 000 gals. per day	Flowing into sewer.
Broken $\frac{5}{8}$-in. service,	100 000 gals. per day	Underground.
Broken $\frac{5}{8}$-in. service,	85 000 gals. per day	Flowing into sewer.
Broken $\frac{5}{8}$-in. service,	87 000 gals. per day	Flowing into sewer.
Blown 6-in. joint,	38 000 gals. per day	Flowing into sewer.
Split $\frac{5}{8}$-in. service,	30 000 gals. per day	Underground.
Broken $1\frac{1}{4}$-in. service,	35 000 gals. per day	Underground.
Split $\frac{5}{8}$-in. service,	27 000 gals. per day	Underground.
Hydrant not seated,	30 000 gals. per day	Underground.

One 10-in., one 8-in., two 4-in., and two 3-in. meters were found to be under-registering, some of them seriously. No case of unauthorized use of water was found.

* Division Engineer, Water Department, Boston, Mass.

The week-day average daily industrial consumption (including schools, armories, factories, power plants, gas works, dairies, sugar refineries, railways and Navy Yard) was noticeably large, amounting to 4 424 765 gals., or approximately 128 gals. per capita. Four customers only, viz., Navy Yard, B. & M. Ry., one sugar refinery and one dairy, were responsible for 3 832 000 gals. or more than three quarters of the whole. In one of these cases there is every reason to suppose that a large waste helps to swell the bill.

Allowing an unavoidable waste of 3 000 gals. per mile of pipe per day, the present domestic daily per capita consumption of the district, as determined by the survey, is 32 gals.

The method of work was essentially the same as that used successfully for many years in Boston, with the difference that the portable pitometer inserted in the pipe through a 1-in. corporation cock, supplanted the permanently located Deacon Meter, and gave greater flexibility of operation. The district, approximately one square mile in area, was divided into twelve sections, the largest of which contained about forty blocks. The average daily consumption of each section was determined by taking the mean of two 24-hour measurements, the flow into the section being through one pipe only, into which the pitometer was inserted and the section being completely isolated from the surrounding distribution system by the closing of all gates around its boundaries. If the minimum night rate was found to be more than one half the average daily rate, it was assumed that avoidable waste existed and the section was subdivided to further locate such waste. This work was done at night during the period of least draft; the flow into the entire section was first measured, then the area of the section was slowly decreased by cutting out block after block.

As the measurement was continuous, the record of the instrument showed the amount of water used in each block, and a leak of any considerable size was quickly apparent. To actually find the leak that it might be repaired, the usual methods were employed,— perhaps the most successful being the use of a steel rod driven down to the pipe at intervals of about 5 ft.; by listening with an aquaphone at the end of the rod, much unnecessary excavation was avoided.

OPERATION OF A TRUE SIPHON ON A MAIN SUPPLY PIPE.

BY WALLACE R. BRANN* AND CHARLES W. SHERMAN.†

[*November 10, 1920.*]

True siphons in water-works practice are of very rare occurrence, — so rare that the writers have not been able to find any published record of the operation of such a siphon. It may, therefore, be interesting to water-works men to learn of the conditions encountered in operating a siphon on a main gravity supply pipe.‡

A supply of water for Hallowell was originally obtained from the head waters of Cascade Brook, about 1.5 miles northwest of the city. Two small reservoirs were constructed on the brook, and a 6-in. pipe laid from the lower reservoir to two distribution reservoirs just west of the built-up portion of the city.

The intake in the reservoir is approximately 8 ft. below spillway level. The pipe leads from the reservoir across a valley perhaps 40 ft. lower, and then rises, crossing a ridge at a distance of about 6 000 ft. from the reservoir. The elevation of the surface here is approximately 9 ft. above the high-water level in the reservoir, and the pipe is about 3 ft. above high water. From this point the pipe descends sharply to the distribution reservoirs, which are about 41 ft. lower than the supply reservoir.

The portion of the ridge lying above the elevation of high water in the reservoir is 500 or 600 ft. in length, measured along the pipe, and it would have been necessary to excavate at least this length of trench in rock, to locate the pipe below the hydraulic grade line.

Hallowell is a city of about 3 000 population, located on the west bank of the Kennebec River, just south of Augusta. The water consumption is not definitely known, but probably approximates 200 000 to 225 000 gal. daily.

The drainage area from which the supply is obtained covers only about one quarter of a square mile, and the quantity to be obtained from it, particularly in dry years, is therefore somewhat less than the consumption of the city. Some years ago an emergency connection was made with

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* Superintendent of Water Works, Hallowell, Me.

† Of Metcalf & Eddy Consulting Engineers, Boston, Mass.

‡ Since the paper was written, the new (1920) edition of the American Civil Engineers Hand Book has been received, which contains the following:

"A siphon installed by George S. Pierson, M.Am.Soc.C.E., of 24-in. diameter cast-iron pipe about 2 900 ft. long with a 20-ft. lift, has been in use for many years, connecting a distant well with one near the pumping station at Kalamazoo, Mich.

"A 24-in. diameter spiral riveted pipe siphon installed by the writer [G. S. Williams] at Taughannock Falls, N. Y., in 1904, has an initial lift of 9 ft., a run of 411 ft., with a rise of 6 in. and a drop of 88 ft. to a water wheel which is supplied through it, and drives a lighting plant furnishing current to the village of Trumansburg. The wheel has a draft tube giving a further drop of 14 ft., and no difficulty has been encountered from accumulation of air when running, the operation head being from 90 to 93 ft."

the pipes of the Augusta Water District, and after a time the operation of the siphon became so unsatisfactory that the entire supply was taken from Augusta. This was the condition in the year 1918 (until December 15), during which year an average of 210 000 gal. per day was purchased from Augusta, at a price of 7c. per thousand gallons, the total bill for the year being $5 367.

Prior to its practical abandonment, the method of operating the siphon was as follows: Valves at the inlet and discharge ends of the supply pipe were closed; the air valve at the summit was opened, and a supply of water from a small reservoir 20 or 30 ft. higher in elevation was drawn through a 2-in. pipe into the 6-in. pipe, to charge the siphon. When all the accumulated air had been expelled at the summit, the air valve was closed and the supply cut off from the upper reservoir; the gates at the inlet and discharge ends of the pipe were opened, and the siphon would operate without attention until a sufficient quantity of air had accumulated at the summit to break the siphon. The efficiency of the siphon began to decrease almost immediately, and gradually fell off until the flow practically ceased. It was the custom to manipulate the valves at 7 and 11 A.M. and 4 and 7 P.M., and under this scheme the siphon was operated with a fair degree of success. The consumption of water at that time is not known, but was probably less than at present.

The connection with the Augusta supply was installed primarily to supplement the inadequate supply from Hallowell's own source. The 2-in. pipe, from which the supply for filling the pipe was obtained, finally gave out, and the siphon could not then be operated, and the whole supply was obtained from Augusta, as above noted. The annual expense of obtaining water in this way was so great that the question of replacing the 2-in. pipe or finding some other method of operating the siphon was raised, and Metcalf & Eddy, consulting engineers, of Boston, were asked to advise the water commissioners in this matter.

The development of the Hallowell water supply had already been made. The water was of excellent quality, but was running to waste for want of a method of utilization, while at the same time the city was paying considerable sums for water to supply this lack. The cost of excavating in rock to lower the pipe over the summit below the hydraulic grade line was practically prohibitive. It was suggested that if some automatic means could be provided by which air could be removed from the summit as it accumulated, there was no reason why the operation of the siphon should not be made continuous and the city's source of supply utilized to its full capacity. An electric-power line crossed the summit in close proximity to the pipe, so that electric power was readily available, and there was no reason to doubt the practicability of providing an automatically controlled air pump for the removal of the air. No definite information as to the quantity of air to be handled could be obtained. From the fact that the siphon had been operated with a fair degree of success

when operating the valves at intervals of four or five hours, it seemed obvious that the accumulation of air could not be very rapid. The matter was taken up with Mr. C. O. Rogers, engineer for the Charles J. Jager Company, of Boston, who suggested the following equipment for this installation:

1 Receiver 24 in. diameter by 36 in. length, of reinforced steel construction, with supporting cradles and 6-in. flanged yoke.
1 Water glass and fittings, for indicating water level in the float chamber.
1 Copper deposit float with necessary connections for the operation of float switch.
1 Triple pole float switch of the enclosed type.
1 Gardner compressor unit, 3 x $3\frac{1}{2}$, air cooled, with extended motor base and belt and idler drive. Capacity of compressor, 8 cu. ft. of free air per minute.
1 $1\frac{1}{2}$ h.p. 3-phase motor, 1 800 r.p.m., for 220-volt current.

After some consideration, order was placed with the Jager Company, for this apparatus.

A vault 12 ft. long, 6 ft. 6 in. wide, and 8 ft. deep, was built enclosing the pipe at the summit, where a tee branch was set, turned up. The air tank or receiver was mounted upon this tee, and a small wooden building previously located over the air valve was placed over the entrance to the vault. Considerable rock excavation was involved in this construction. The total cost of the installation is estimated as follows:

Pumping equipment, including air tank, etc.	$643
Vault, about	800
Installation and connection of apparatus, about	100
Total	$1 543
Say	$1 600

The apparatus was put in operation on December 15, 1918, and has been in practically continuous service ever since. The motor operating the pump was burned out some time later, due to a drop in voltage on the electric-power line, and through no fault of the apparatus. The operation is entirely automatic, and the siphon is maintained in continuous operation. It is, of course, necessary to throttle the valve at the discharge end of the supply pipe where it enters the distributing reservoir, in order to prevent breaking the siphon, due to the excessive drop in this leg of the siphon, and also to avoid depleting the reservoir too rapidly.

It is still necessary to obtain water from Augusta to supplement the inadequate supply from the local source, particularly at times when the consumption is high. During the year 1919 an average of 84 000 gal. per day was so obtained, at a cost of $2 146. During this same year the cost of electric power for operating the vacuum pump was $85, the price being 9c. per kw.-hr., and in addition the cost of electric lights for the vault was $9, making a total cost of electric current $94. If interest and depreciation on the investment be assumed at 7 per cent., or $112 per year,

the total cost of operating the siphon during 1919 was \$206. Adding this sum to the cost of water purchased during that year, makes the total cost of the water supply \$2 351, or \$3 016 less than the cost for the year 1918.

A similar comparison for the first six months of 1920 is as follows:

Cost of water bought from Augusta (110 000 g.p.d.)	\$1 396
Cost of electric current	66
Interest and depreciation	56
Total	\$1 518 for 6 months

or \$3 036 per year, — which indicates a saving of \$2 331 for 1920 as compared with 1918.

When the apparatus was first installed, the pump operated only about once an hour. It was found, however, that at times when the water in the reservoir was comparatively low, much more air accumulated, and in July of this year the pump was found to be operating about once in five minutes. The difference in water level in the receiving tank, between the time of starting and stopping the pump, is about 6 in., corresponding to an accumulation of air of approximately 3 cu. ft.

It is probable that when the water in the reservoir is low, more air enters the pipe at the inlet end in solution or in suspension in the water, and it is also possible that some air is drawn in by vortex action. The period of low water in the reservoir also corresponds to the time of low ground water, when a greater amount of the pipe which is above the hydraulic grade line, and therefore subject to negative pressure, is above ground-water level. Under these circumstances more air would probably be drawn into the pipe, through joints, than when ground water is high.

The pump maintains a vacuum of approximately 21 or 22 in. of mercury, corresponding to about 24.5 ft. of water. The hydraulic grade line at the siphon is therefore about 24.5 ft. below the pipe at the summit of the siphon, and 20 or 21 ft. lower than the water in the reservoir.

Discussion.

Mr. Frank A. Barbour.* Some ten years ago a siphon was put in at Woburn, which connects some twenty-five driven wells with a well adjacent to the pumping station. I think the high point in the pipe line is perhaps ten or twelve feet above the hydraulic gradient. The siphon was laid on a rising gradient to a point immediately over where it dropped into the receiving well. At this point a tee was placed in the line, similar to that described by Mr. Sherman, and connected by 2-in. pipes to a steel tank in the station. Connected with this tank is an air compressor, reversed, operated by a Pelton wheel, driven by the city pressure, with discharge back into the well. This air pump was designed to start auto-

* Consulting Engineer, Boston, Mass.

matically, but since it only has to be operated about once or twice a day, the automatic attachment was disconnected. The siphon has worked successfully, so far as I know; it is 14-in. pipe, about 1 400 ft. long.

Past-Pres. Edwin C. Brooks. The Cambridge Water Works had in operation a 30-in. cast-iron pipe line from Stony Brook reservoir to Fresh Pond, and near Fresh Pond there was a summit that was above the hydraulic gradient. After that pipe was laid for some time we had no apparent trouble from it. It seemed to work perfectly, and there was no accumulation of air, but gradually it commenced to fail and an investigation was made. The pipe ran along before it got to this summit covered rather light, not much over 3 ft. In investigating we dug up the joints along in this level stretch of street, and when those joints were uncovered, and we tried to drive them, it sounded like driving a loose hoop on a tub or barrel. The lead seemed to be loose in the joint, notwithstanding the fact that those joints probably had been faithfully driven.

The joint seemed to be loose in the bell, and the question occurred whether it was not possible that, there being a shallow cover there, and the water flowing through the long line of pipe and becoming warmer after standing in the pond or reservoir — it had not expanded the pipe, and then the chill of winter, the frost going down, had contracted the lead or contracted the pipe, so that these joints had gradually been compressed. But, anyway, for a long distance — I should say, roughly speaking, 500 or 600 ft. — the joints seemed to be quite loose, and were driven up. Part of the 30-in. line was supplanted by the 53-in. conduit, built by Mr. Coffin, so that that portion of the pipe has been out of use.

Mr. Raymond F. Bennet.* Some twenty years ago, there was a 16-in. siphon in successful operation at Richmond, Ind. Possibly that is the one that Mr. Gardner Williams had a report of. Mr. Howard A. Dill, a member of this Association, could probably give information concerning it. I think it is still in use.

Mr. D. A. Decrow.† In Auburn, N. Y., there was a 24-in. pipe laid, 9 000 ft. long, and used as a siphon. It had an elevation, I think, at the high point, of something like 9 ft. The original installation was intended to be laid at a grade, but they struck quicksand, and kept above it. This discharged some 6 or 7 million gal. a day. They installed a pumping station at the lake, but found it was not necessary to use it. They did, however, have to remove the air from the high point. There was no difficulty in delivering all the water needed. The pipe was laid in 1885.

Mr. Robert Spurr Weston.‡ Just by way of reference to this paper, I might say that some fifteen years ago I called special attention to the rubber rings to be used in a joint of this kind.

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* Contractor, Portland, Me.
† Of Worthington Pump and Machinery Company, New York.
‡ Consulting Engineer, Boston, Mass.

TOPICAL DISCUSSION.

Fire in Coal Piles.

President Macksey. Is there anybody here who has had experience in applying water to extinguish a fire in a coal pile?

Mr. Harry A. Burnham.* Once in a while the members of the Mutual companies have that problem to contend with. It is usually the case that the coal has been in the pile a long time, and that the fire is deep down at the bottom. We find about the only satisfactory way to handle that is to shovel it out. That is attended with some hazard, but if the hose is kept ready you can usually prevent the fire from getting away. The fire can be located by sinking 1-in. pipes tapped at the lower ends in which a thermometer can be lowered. The heated part should then be removed by digging, using as many men as can be worked to advantage. The hot coal should be drenched as it is exposed, so permitting the men to dig in until all the hot coal has been removed.

Mr. Stephen H. Taylor.† I think Mr. Burnham perhaps will back me up when I say that some of the coal piles are piped to the bottom with perforated pipe so that water can be gotten into them.

Mr. Burnham. There have been cases where that has been tried.

Mr. Taylor. It has been successful, hasn't it?

Mr. Burnham. Fairly so. They use that pipe at times for determining the temperature near the bottom of the pile, by dropping thermometers down through the pipe. In that case you know the condition of the pile before the fire occurs and can shovel the coal out before there is any fire. When this method is used a 2-in. pointed pipe, with 3 or 4 ft. of its length perforated with $\frac{3}{8}$-in. holes, is driven into the pile and water forced into it through a hose line. Care should be taken that the men are not allowed to stand near when the water is applied, as there is some possibility of explosion due to formation of steam.

Mr. Richard D. Chase.‡ About two years ago, in Superior, Wis., I saw a large coal pile with fire running through it in all directions. The pile may have covered an acre or more and was from 15 to 20 ft. high. They have had much experience in Superior with coal fires, for there the coal is accumulated during the summer, stored on the piers and shipped out during the winter. It is evident that they had no better way than overhauling and wetting down. There was a permanent wrought-iron pipe alongside the loading track, temporarily connected to the nearest shore

* Inspector and Engineer, Associated Factory Fire Insurance Company.

† Assistant Superintendent, Water Works, New Bedford, Mass.

‡ New Bedford, Mass.

hydrant. Hose lines were taken from the pipe where needed. The coal was being dug out with a steam shovel, quenched with water when necessary, and loaded into cars for shipment. The fire did not come to the surface, and as it was broken down only a small percentage showed signs of fire; this occurring in veins, only. The action was perhaps more like coking than burning.

MR. WILLIAM F. SULLIVAN.* Some of the experts on coal-pocket fires now advise against the use of water, but are using some sort of a chemical preparation, bicarbonate of soda, probably. I have seen a device or nozzle advertised which is connected to a hose, and this nozzle is driven to the bottom, from which the water finds its way through the pile.

VIBRATION IN HOSE, PRODUCING HEAT.

MR. CHARLES W. SHERMAN.† Mr. Sullivan's mention of an unusual device calls to my mind a clipping which was shown me a few days ago, — a new cotton hose was being tested with a fire stream and it burst into flames. The clipping stated that some expert had determined that the cause was the friction of the water through the hose.

MR. BURNHAM. My impression of the investigation which was made is that the hose was used in connection with a pumping engine which caused a great deal of vibration of the hose, it being run at high pressure, and the outer and inner jackets of the covering of the hose were supposed to have chafed on each other, to the extent that the jacketing was injured by the heat.

MR. TAYLOR. I talked with one of the engineers of the New England Bureau, who conducted the test after this fire that Mr. Sherman speaks of, and he said that they did produce that effect by running with a throttled valve. This did not furnish water enough to completely fill the hose and caused vibration and friction between the rubber lining and cover. The heating was very noticeable and increased, until finally it smoked and burst into flames. This was done after the fire to see if the burning could be reproduced.

It has been found that this effect can be produced on any brand of hose under similar conditions.

MR. BURNHAM. I might say that there is a great deal of vibration in the hose if the pump does not act smoothly, and it is very conceivable if you operate under conditions of that kind, for a long enough period, that you can produce heat.

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.
† Of Metcalf & Eddy, Boston, Mass.

RECENT PROGRESS IN THE STANDARDIZATION OF THREADS FOR FIRE-HOSE COUPLINGS AND FITTINGS.

F. M. GRISWOLD.*

[*September 9, 1920.*]

GENTLEMEN, —

Assuming that you will be interested to be advised as to the progress being made in the standardization of threads for public fire-hose couplings and fittings, it affords me pleasure to present to you the following additional facts as in evidence of the widespread and growing interest in the matter shown by many public officials and municipalities in their acceptance and adoption of the National Standard Hose couplings, as per the specifications approved by this Association, which, as you doubtless will recall, provide for a coupling of $3\frac{1}{16}$ in. outside diameter over the male end thread, with $7\frac{1}{2}$ threads to the inch, to conform to the dimensions of which it is practicable to readily convert other screw couplings to serviceable interchange with the standard when the range of diameters fall within the limits of from 3 in. to that of $3\frac{3}{32}$ in., with threads of either 7, $7\frac{1}{2}$, or 8 to the inch.

The process of conversion is remarkably simple and inexpensive, as has been demonstrated when such conversion has been secured by the use of the special tools and devices perfected through the efforts of the "Committee on Fire Protection and Engineering Standards" of the National Board of Fire Underwriters.

A detailed and illustrated description of these tools was presented (in pamphlet form) to this Association when last I had the pleasure of bringing the matter to your attention; some 14 000 copies of this pamphlet have been distributed broadcast throughout this country, resulting in an encouraging awakening of public interest, as has been evidenced by the many inquiries in relation to the matter received from water-works and fire department officials, state fire marshals, fire insurance companies, manufacturers of fire apparatus, and fire underwriters' inspection bureaus.

In addition to the results attained as set forth in the text of the pamphlet referred to, addresses and demonstrations have been made at conventions of state firemen's associations. Circular letters were also sent to all state fire marshals and insurance commissioners and to all fire chiefs in cities of over 20 000 population, with a view to arousing the widest possible publicity and soliciting active coöperation forwarding the work of standardization of fire-hose threads in the territory under jurisdiction and control.

* General Inspector, Home Insurance Company.

The Committee of the National Board of Fire Underwriters plans to make other exhibits and conduct further demonstrations in various parts of the country, in order to stimulate state-wide activity in securing complete standardization in the near future.

That these activities have been productive of very substantial results is evidenced by the fact that one or more sets of standardization tools have been purchased by the underwriters' inspection bureau or the state fire marshal's office having jurisdiction in Connecticut, Illinois, Indiana, Kentucky, Michigan, Minnesota, New Jersey, Pennsylvania, Tennessee, and West Virginia, preparatory to starting the work of standardization in their respective states; and it is gratifying to be able to record the fact that the work of standardization recently accomplished in the state of Michigan by the Michigan Inspection Bureau, in coöperation with a committee of the Michigan State Firemen's Association and the state fire marshal's office, is not only typical of the movement being initiated in several other states but is remarkable at the same time in its demonstration of the practical results which may be accomplished through the use of these standardization tools by those not specially trained in their operation, it being a fact that with one set of these tools in charge of an engineer provided with an auto runabout, the first week's work in Michigan resulted in the complete standardization of all hydrant hose outlets, hose couplings, and special fittings in four municipalities. It is now planned to place at least two men in that field, each in charge of two sets of tools which are to be available for continuous operation in order to assure complete standardization throughout the state within the next two years.

It will interest you to be advised that since this initial effort the number of towns in the state of Michigan which have been standardized by means of these special tools and devices has been increased to fifteen by the 3d of the present month, as per advices this day at hand, and that the good work is being actively progressed with most gratifying results.

The towns in which the work of standardization has been completed, together with information as to their population, diameter and pitch of thread, number of hydrants treated and number of parts of apparatus re-cut, is as follows:

Town.	Population.	Diameter.	Pitch.	Hydrants.	Parts
Berrien Springs.......	900	3.049 3.071	$7\frac{1}{2}$	32	64
Cassopolis............	1 600	3.092 3.148	8	50	100
Constantine..........	1 500	3.014 3.064	7	47	156
Decatur..............	1 500	2.981 2.992	$7\frac{1}{2}$–8	40	218
Dowagiac............	5 500	3.000	8	106	643
Lawton..............	1 100	3.007 3.060	$7\frac{1}{2}$	23	47

Town.	Population.	Diameter.	Pitch.	Hydrants.	Parts.
Marcellus	1 100	3.061 3.076	8	40	145
Mendon	1 000	3.003	8	18	110
Mount Clemens	10 000	3.003	$7\frac{1}{2}$–8	250	2 153
Niles	7 000	3.036 3.094	8	206	515
Paw Paw	2 000	3.072 3.082	8	40	132
Schoolcraft	800	3.000	$7\frac{1}{2}$	34	112
Sturgis	6 100	2.994 3.031	8	110	618
Three Rivers	7 000	3.083 3.093	8	160	540
Vicksburg	2 000	3.000	7	48	301
	49 100			1 204	5 859

Particular attention is called to the fact that the work of conversion carried out in each of the towns tabulated was performed on couplings, hydrant outlets, and other utilities showing variations from the National Standard dimensions of $3\frac{1}{16}$ in. over male thread ranging from 2.981 in. to 3.148 in. and covering pitch of thread of 7, $7\frac{1}{2}$, and 8 threads to the inch, in two instances both $7\frac{1}{2}$ and 8 threads being found in the respective equipments.

The conditions as presented in the above tabulation brought into play and practical test every function of these conversion tools save that of reduction of thread on male ends of excess diameter, it being necessary in each instance to expand the male end, recut its thread and tap-out the female member to standard dimensions, the total operations covering nearly 6 000 separate items in recutting the various parts, all of which was accomplished with such remarkable and gratifying results as to encourage the hope that this demonstration of practical results in the conversion of such public utilities may serve to convince the skeptical and spur the progressive official having jurisdiction, to push the good work to an early completion in all sections of this country where non-conformity to the National Standard Hose coupling may still be in evidence.

This brief résumé of recent progress in the work of standardization, added to that heretofore reported, certainly encourages the hope of its ultimate success in all sections of this country, at no distant day, if this Association and all other organizations interested in securing uniformity in these highly essential public utilities will more earnestly and energetically coöperate in carrying out the work of complete accomplishment, and I therefore appeal to the members of this Association to prove their faith in this standard, approved and sponsored by this Association more than seven years ago, by bringing the equipment of their several cities and towns into conformity to the National Standard, to the end that the vested interests of the community may be more surely safeguarded and the jeopardy of loss of human life by fire be thereby minimized.

MODERN PUMPING STATION DESIGN AND OPERATION.

REEVES J. NEWSOM.*

[*September 10, 1920.*]

It has been necessary within the last two years, in order to keep abreast of the times and to get proper efficiency in operation, to make three typical changes in our pumping station equipment. A motor-driven centrifugal pump installed in 1912 in the Glen Lewis station had been so outgrown by the progress in design of this type of pump that it was economical to junk the equipment and replace it with new.

The Walden Pond station, equipped with a steam-driven pump, became uneconomical and impractical to operate, and unable, because of its peculiar situation and the difficulty in obtaining men for its operation, to supply the amount of water needed: and it has been supplanted by a new station in a different location, with electric motor-driven centrifugal equipment.

In the main pumping station, which pumps daily into the mains and equalizing reservoir, the coal situation has become so involved that we have found it necessary to change to oil as fuel for the boilers.

The Glen Lewis equipment consisted of a centrifugal pump delivering about 15 million gallons per day against a 20-ft. head driven by a 100 h.p. synchronous motor with suitable switchboard and starter. The priming pump was of the ordinary reciprocating type, belt driven from a small motor. There was no water meter installed with this pump, and for six years it was run without any idea of the efficiency at which it was operating.

In 1918 the writer ran a series of tests, using a Petot tube meter for measuring the water, and found that at rates from $12\frac{3}{4}$ millions to $16\frac{3}{4}$ millions per day against heads ranging from 10.9 ft. to 27 ft. the combined efficiency of the unit varied between 26 per cent. and 47 per cent. This unit has now been replaced by a pump which delivers about 17 million gallons per day against a 20-ft. head driven by a 75 h.p. induction motor at 500 r.p.m. The auxiliary equipment is in all respects identical with that at the Hawkes Pond station, as is also the method of operation, which will be described later. This pumping unit at the time of its acceptance tests showed a combined efficiency of 74.5 per cent.

The Walden Pond station, built in 1902, received water into the suction well through a canal about three quarters of a mile in length. When in operation two men were required at all times to attend to the screens at the end of the canal and to control the flow of water. The equipment

* Commissioner of Water Supply, Lynn, Mass.

in the station consisted of a cross-compound Corliss engine, the piston rods of which were extended through the cylinders and the pump attached beyond. Because of the arrangement of suction canal, discharge lines, etc., water which needed to be lifted from one pond to another only 20 ft. higher was actually being pumped against a 45-ft. head.

This station was used to pump water which flowed by gravity from the Saugus River to Hawkes Pond during the winter and spring months. Due to the necessity of getting together a force of engineers and firemen, it could only be operated when a steady run of water of at least two or three months' duration was assured, and to-day, of course, it would be impossible to get together a force of men for a short term job of that kind. Short flood flows in the river could never be utilized, and the consumption of water by the city demands more than the steady spring flows will yield.

All these difficulties were overcome by building a new station on the shore of one pond, at a point only 500 ft. from the other, and equipping the station with a motor-driven centrifugal unit. This location reduced the lift to 23 ft., including piping losses, and the starting and stopping of the plant is so simple that all flood flows can be taken advantage of, even though they are of only one day's duration. This has practically doubled the value of the Saugus River as a source of supply.

The equipment in the new station consists of a centrifugal pump capable of delivering 21 million gallons per day against a 23-ft. head, and is driven by a 100-h.p. induction motor at 450 r.p.m. This motor, as well as the one at the Glen Lewis station, is wound to use 4 000-volt, Y-connected current direct from the transmission line without a transformer.

The auxiliary equipment in both stations includes a two-panel switchboard, a water meter, and a priming unit, and in the Hawkes station a $\frac{1}{4}$-in. mesh copper screen of the revolving endless-chain type, with suitable washing pan and hot- and cold-water connections for cleaning off dirt and ice.

The switchboards contain both electrical and water instruments, consisting of the following: voltmeter, ammeter, oil switch of the remote control type, lighting and priming pump switches, overload release, under voltage release, inverse time limit over load release, the power company's watt-hour meter, and a curve drawing wattmeter; a clock, indicating discharge and suction gages, and recording discharge and suction gages. On the back of the panel and wired in series with the under voltage release is mounted a diaphragm suction regulator which shuts down the pump just before it loses water. The water meters are indicating, recording, integrating instruments, actuated by Petot tubes.

The priming pumps are novel adaptations of a direct-connected motor-driven hydro-turbine vacuum pump, and, complete, occupy a space only 20 in. by 40 in. They are so compact that they are tucked under the outboard bearings of the pumps, and in general appearance are a part of the big units and add practically no space to the area which they cover.

The Hawkes Pond unit showed on its acceptance test an over-all efficiency of 77 per cent.

These two motor-driven installations are on the supply system where absolutely continuous operation is not essential, and we are able, in view of this fact and the safety devices which are provided, to operate them twenty-four hours per day for weeks at a time, practically without attendance. The only labor involved is the daily changing of charts and reading of meters, and the occasional supplying of a small amount of oil to the bearings. This is done at both stations by the patrolman on the respective parts of the reservoir system, so that there is no labor chargeable to the operation of the stations.

The Walnut Street station is equipped with a 15-million-gallon-per day turbine-driven centrifugal pump, and two reciprocating crank and flywheel pumps, 10 million and 5 million gallons per day capacity, respectively, power for which is furnished by two 175-h.p. boilers. There is also a motor-driven centrifugal auxiliary pump of 3¾ millions per day capacity, for which we purchase power from the local electric light company. As our consumption is about 9 million gallons per day, it is essential that at least one boiler be in operation at all times in addition to the electric unit, and ordinarily all the pumping is done by steam, using both boilers.

The coal problem has become very serious in two ways. At times coal is scarcely obtainable, and last winter for several weeks we had to depend on trucks coming through the deep snows from a city twenty miles distant, to keep our pumps going. Then, too, the quality of the coal now on the market has made its use very uneconomical. The station duty has dropped as much as 30 per cent. at times, and in order to keep up steam there has had to be wasted, unburned, through the ash pit, 18 per cent. to 20 per cent. on the average, and, at times, as high as 28 per cent., of the coal fired. Combined with these facts has been the ever-rising price of coal from around $4.00 per ton to $16.50 at the present time.

We have made a contract for oil at the equivalent of about $9 per ton for coal, and the price is guaranteed for two and one-half years, and the delivery of the oil for five years. This contract is backed by a $10 000 bond, which is two thirds of the cost of the oil-burning apparatus, and the amount to be saved is such that if the oil company delivers oil for only a few months we can change back to coal without loss.

The oil situation appears to be pretty stable, however, when it is remembered that enormous royalties are paid to the Mexican government on the output of oil, and it is, therefore, vitally interested in keeping them in operation; and further, any interference with the oil output would not be tolerated by the British and American navies. The company who furnishes the oil into trucks from storage tanks in Chelsea, Mass., owns also the wells, the pipe lines, and tank steamers which bring it to this country, so that transportation difficulties would seem to be minimized.

The oil-burning apparatus which is being installed consists of three

principal elements, the storage tank, the combined pump and heater, and the burners, with connecting piping and auxiliaries.

The storage tank is of reinforced concrete, built in two separate compartments with a total capacity of 35 000 gal., or about three weeks' supply. A suction pipe comes from each compartment of the tank and runs to the pump inside the boiler room. These pipes are surrounded near the end by steam jackets which heat the heavy fuel oil so that it will flow. Pipes extending to the bottom enter the tank at the same points, to which ejectors can be attached for removing water which may collect from time to time.

The pump to which the suction pipes are attached is of the double duplex direct-acting type, mounted above the heater which is cylindrical in shape, the whole thing being a small, compact unit. The heater is constructed like a surface condenser, the steam being inside the tubes and the oil flowing around them. In this heater the temperature of the oil is raised to about 130 degrees Fahr.

From the heater the oil is pumped to the boiler front, where it passes through an auxiliary heater composed of another steam jacketed section of pipe which is used to heat the oil beyond the pump when the boilers have been banked, or when for any reason the main heater does not function properly. The piping is so arranged that all exhaust steam from the heaters and pump is returned to the boilers.

The oil then passes through a regulator and to the burners, where it is atomized by steam and mixed with air. The burners are placed just below the location of the coal grates, the pipes coming in through the ash doors, which are entirely bricked up except for the requisite air slots.

The regulator is actuated by changes in steam pressure, and controls the flow of oil to the burners. The supply of air is controlled by the position of the chimney drafts. It is possible to obtain a regulator which will also control the air, but a centrifugal pump load is so steady that practically no change is required in the amount of air needed, once it has been set to meet the atmospheric conditions for the day's run, and the complication of such a regulator is not, therefore, justified in our installation.

We use both boilers ordinarily to carry the load, and, to prevent its unequal distribution and the overloading of either of the boilers, steam-flow meters are being installed to show the respective outputs.

The dangers in the use of oil are two, — having too hot a fire and having the fire too concentrated. The limit to which an oil fire can be forced is usually beyond the safety point of the boiler, and so the output must be watched. If the burners are too close to the boilers the flame may be so concentrated that the rivets in the shell will melt. A boiler setting built especially for oil is usually very high, but a coal installation can in most cases be adapted to oil by removing the grates and putting the burners in the top of the ash pits.

The principal advantages which will in our case be derived from the use of oil are as follows:

1. Oil is cheaper than coal.
2. It can be burned more efficiently than coal.
3. Greater boiler capacity can be developed.
4. Coal and ash handling charges will be eliminated.
5. Variation in quality will be minimized.
6. Banking of fires can be done very much more economically.
7. Neater and cleaner and better working conditions will be obtained.

The burning of oil seems to solve our problem in this station, temporarily, at least, and perhaps until such time as the eventual solution, the development of available water power, will be consummated.

Under favorable conditions, steam power can be developed and used more cheaply in Lynn than electrical power; but in the case of the two stations mentioned above, which are situated on the supply system, and which are operated only a part of the time, the difficulty in obtaining labor, and the higher fixed charges on steam-driven equipment, more than offset the higher cost of operating by electricity.

CLEANING AND PAINTING STANDPIPES.

BY CHARLES W. SHERMAN.*

[*December 8, 1920.*]

What I have to say relates not so much to cleaning and painting standpipes as to the effect of corrosion upon a standpipe which went without cleaning and painting inside, for a period of twenty-nine years. This is a longer time than most of us would dare to leave such a structure without examination and cleaning, but in this particular case the difficulties of throwing the standpipe out of service were so great that the water commissioners preferred to take what risk there was, rather than to attempt to operate the works by direct pressure for a sufficient period to clean and paint the tank.

This standpipe is at Needham, Mass., and was built in 1891, or twenty-nine years ago, by E. Hodge & Company, East Boston. It was designed by one of our old members, Mr. Louis E. Hawes. It is 25 ft. in diameter and 85 ft. high.

At the time it was built, the standpipe was painted inside by the makers, but had no further treatment on the interior until this year, when it was thoroughly cleaned by hammering and wire brushing, and well painted with red-lead paint.

The original construction included a riser pipe, extending to about 3 ft. below the top of the tank, supported by ties of wrought-iron rods, connected to the side of the tank. During the severe weather of last winter, the ice tore away the ties, and the riser pipe collapsed.

An additional standpipe having been provided two or three years ago, it was practicable to throw this tank out of service long enough to remove the ruins of the riser, and to clean and paint the tank. I was fortunate enough to have opportunity to examine the condition after the interior had been painted, and obtained a couple of photographs which show in an interesting manner the results of corrosion during the twenty-nine year period.

The most significant photograph, Fig. 1, shows one of the plates of the lowest ring near one of the vertical joints. The pittings are very noticeable in the photograph. Most of them are from $\frac{3}{4}$ in. to 1 in. across, and of a depth a little over $\frac{1}{16}$ in. Some have a depth approximating $\frac{1}{8}$ in., and extend in a vertical direction as much as 6 in., or even more in some cases.

It is very interesting to note the groove immediately adjoining the vertical joint. It seems probable that this results from the bending of the

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

plate, resulting from expansion and contraction and the greater stiffness of the lapped joint. This bending, while doubtless very slight, apparently has been sufficient to throw off scale as fast as it formed, and thus to expose fresh metal to the action of the water, in this way causing more continuous corrosion than at any other point.

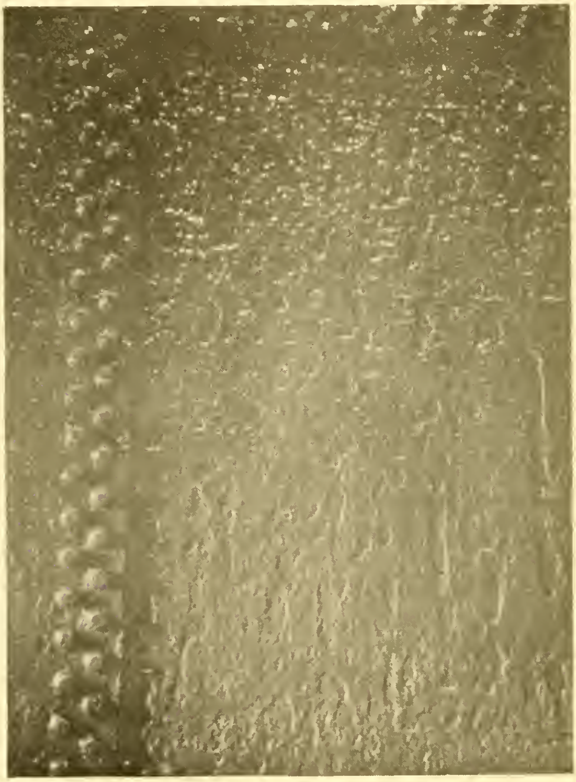

FIG. 1. SIDE PLATES OF STANDPIPE AT NEEDHAM, MASS., SHOWING EFFECTS OF CORROSION.

This explanation seems to be substantiated by the fact that a similar horizontal groove is to be noticed just above the edge of the holding-down brackets, where there must have been a slight amount of bending, resulting from the swaying of the standpipe in a heavy wind.

I did not have opportunity to examine the upper plates closely, but, as far as I could tell from the floor, it appeared that the corrosion in the upper part of the tank was very much less; in fact, almost none was noticeable in the upper 20 ft. or so, and it gradually increased in amount to the bottom ring of side plates.

The bottom, or floor plate, of the tank seemed to be substantially free from corrosion, probably on account of the protection afforded by the sediment which collected in the tank.

I have not made any computations of the loss of strength resulting from the pitting, but it seems probable that the reduction in area in the plates of the lowest ring, which were originally $\frac{3}{4}$ in. thick, is no greater

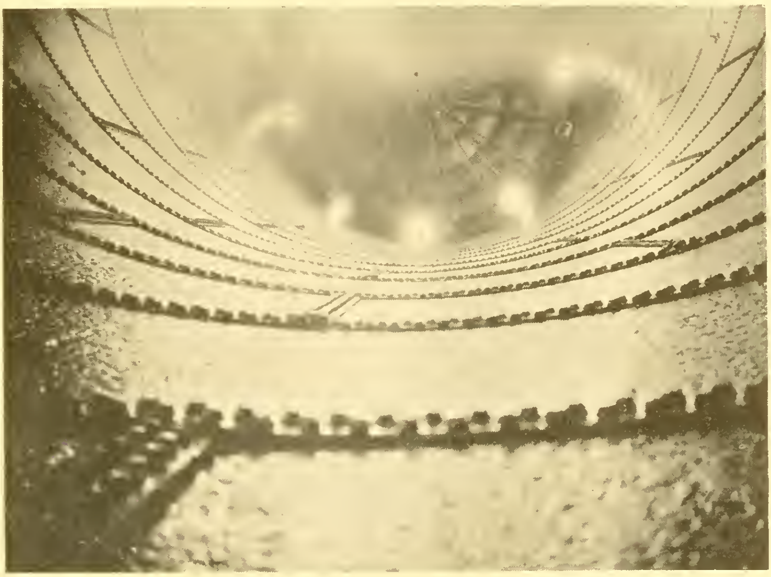

FIG. 2. INTERIOR OF NEEDHAM STANDPIPE, LOOKING UPWARD.

than that due to the rivet holes in the riveted joint, and that the factor of safety of the tank has not been materially reduced by such corrosion as has been suffered up to this time.

I should hesitate to quote this experience as a reason for leaving a metal standpipe unpainted for a long period. Doubtless the fact that this particular tank was of wrought iron had much to do with the fact that the damage was not more serious, and very probably, also, the character of the water was an item of importance.

The red-lead paint has the appearance of being very well applied, and will, I believe, adequately protect the tank for a considerable period. I should not advocate, however, leaving it without examination for a longer period than three or four years, particularly as additional corrosion at the points where the thickness is already reduced might seriously affect the safety of the tank.

Discussion.

Mr. Reeves J. Newsom.* I should like to ask Mr. Sherman how the average height of water in that standpipe compared with the fact that the top 20 ft. was not pitted as badly as the rest.

Mr. Sherman. I can't tell very positively, not having an intimate knowledge of the operation of the works, but it doubtless was the fact that the upper plates were alternately dry and wet. Certainly the water occasionally slopped over the tank, and also it must have been down 20 ft. or more below the top, from time to time. The fact remains, however, that the pitting was progressive as you went up to a point something like 20 ft. below the top.

Mr. Samuel E. Killam.† Have you any theory as to why the axis of the pits is vertical instead of horizontal?

Mr. Sherman. I imagine it has something to do with the rolling of the plates, but I don't know anything about it.

Mr. Morrison Merrill.‡ I should like to ask Mr. Sherman if he will tell us what he considers the best compound to use in painting a large standpipe on the inside.

Mr. Sherman. The paper presented a couple of years ago was designed to bring out experience in that line and try to find out how different paints had acted. Of course the differences in the character of the water and the exposure of the tank have a great deal to do with the case. Probably still more depends on the thoroughness of the cleaning of the tank before it is painted. But, taking it by and large, and for average conditions, I was unable to find anything that offered as promising results or that had satisfied as well, where I could get information, as red lead.

Mr. Merrill. I might say for the benefit of the members that I had a little experience, a year ago this summer, with a standpipe 40 ft. in diameter and 60 ft. high, of practically the same construction as this standpipe we have seen illustrated on the screen. It was five years since that had been painted. There was 8 in. of sediment in the bottom, — mud, iron rust, and one thing and another. The plates up to 30 ft. were badly corroded and badly pitted; above that they were practically as good as the day they were put in. The standpipe was cleaned up to 30 ft. twelve years ago; it had been painted but one coat of paint from that time until a year ago this summer, when it was painted with two coats of red lead. At that time it was thoroughly wire-brushed and cleaned, dried out and painted. When the first coat was dry we put on a second coat, and thirty-six hours after the second coat was finished we put the water into the standpipe. I opened that standpipe the twelfth day of October just past, and found that the paint is just as hard or harder than the iron itself, with the

* Water Commissioner, Lynn, Mass.

† Superintendent, Metropolitan Water Works.

‡ Superintendent, Water and Sewer Department, Wakefield, Mass

exception of one or two places where the iron rust was not wholly taken off and the paint did not get a good grip on the iron itself. That standpipe is in Wakefield.

Mr. H. K. Barrows * (*read by the Secretary*).

MEMORANDUM ON COST OF CLEANING AND PAINTING STEEL STANDPIPES.

Tanks at Fall River.

These are four in number, of the following dimensions:

Townsend Hill, 1 tank, 73 ft. in diameter by 37 ft. high.
Bedford Street, 2 tanks, each 65 ft. in diameter by 56 ft. high.
Haskell Hill, 1 tank, 65 ft. in diameter by 55 ft. high.

The total area of surface, including outside and inside of tanks and bottom, is about 99 300 sq. ft.

In 1915 the four tanks were cleaned by scraping, and painted inside, bottom, and outside two coats of Detroit graphite paint.

Paint, furnished by the city, cost	$1 167.98
Labor cleaning and painting, by contract, cost	1 036.80
Total	$2 204.78

Or about $22.20 per 1 000 sq. ft. of surface.

In 1919 the four tanks were cleaned by scraping, and painted inside, bottom, and outside one coat of Detroit graphite paint.

Paint, furnished by city, at cost of	$1 320.25
Labor of cleaning and painting, day work, cost	896.00
Total	$2 216.25

Or about $22.30 per 1 000 sq. ft.

Note that the cost per 1 000 sq. ft. was almost identical in 1915 and 1919, but in the former case included two coats of paint and in the latter case but one coat.

Standpipe at Gardner State Colony, Gardner, Mass.

This is 25 ft. diameter by 82 ft. high, with conical roof 20 ft. higher. It was cleaned by scraping, and painted in 1916, two coats inside and outside, of red-lead paint, —"Government formula," — at a total cost of $458, the state purchasing the paint and contracting for labor.

The total area covered was about 15 200 sq. ft. of surface, or at the rate of about $30 per 1 000 sq. ft.

Mr. Henry A. Symonds.† As an illustration of the different action of waters on the interior of steel tanks, I will mention two tanks recently cleaned and painted.

* Consulting Engineer and Assoc. Professor Hydraulic Engineering, Mass. Institute of Technology.
† Consulting Engineer, Boston, Mass.

The first tank, located on Cape Cod, was painted by the manufacturers when built, and repainted in about four years. When emptied this tank was found to be coated by hard scale which had to be chipped off with cold chisels.

In the second tank, located about thirty miles south of Boston, in place of the hard scale and tubercles appeared a soft, pasty coating which could almost be scraped off by the hand. The second was not painted for approximately two years after the first, but was in much better condition on the inside.

The waters were in both cases from well supplies, and very similar in their analysis, some elements, of course, being different on the Cape than farther inland. Both waters were very soft.

Within the last eight years several tanks in eastern Massachusetts have been painted with a compound which seemed to be a mixture of tar and some other materials, and was known as Main's Hot-coat. In several cases this has shown remarkably good results, and after several years there has seemed to be no material deterioration in the quality of the paint. In one case large scales came off during the second winter, but it was found that this was due to having imperfectly cleaned the tank, as the interior of the scales which came off were coated with a film of rust.

One of the dangers in using a heavy coat of this kind is that if it does not prove satisfactory, it is very difficult to remove, and proved the case in the tank cited.

From the summary of opinions by those best able to judge, I am convinced that red lead, for a first coat at least, proves about the most satisfactory of any form of paint which has been used for steel water tanks.

There is, however, a great deal to the question of painting besides the character of the paint. Perfect cleaning and the method of application are perhaps as important as the quality of the paint itself.

The study of the inside of some tanks has shown that with the ordinary painting more or less thick bodies of paint are left upon the surface of the metal. In many of these cases it will be found that water is contained under the paint, and usually more or less pitting has occurred at these points.

The secret of first-class steel tank painting is to *be sure of a clean surface* and *rub the paint out to a uniformly thin film*, which will become hard and adhere to the steel rigidly.

FIRST REPORT TO THE NEW ENGLAND WATER WORKS ASSOCIATION OF THE COMMITTEE ON UNIFORM ACCOUNTING.

(For Municipal Water Works Especially.)

[*September 9, 1920.*]

(Compiled for the Committee by A. R. Hathaway.)

To the New England Water Works Association,
in Annual Convention Assembled at
Holyoke, Mass.

Gentlemen, — Your Committee on Uniform Accounting, after many abortive attempts and futile struggles to do something to merit their appointment, beg leave to submit the following preliminary report, with its accompanying indicated arrangement for a simple but comprehensive scheme of modern accounting requirements, for possible approval and later adoption by water utilities by recommendation of the Association.

At the annual convention of the Association, held in September of 1916 at Portland, Me., there was read and discussed a very able paper submitted by Mr. Edwin L. Pride, certified public accountant, of Boston, on the subject of "Water-Works Accounting"; and as a result of this paper and discussion of the subject it was voted that the President of the Association appoint a committee to study the subject and submit recommendations in the matter, and that in such study the committee take into account available previous investigations of the subject made by other water works associations, by the Washington Bureau of the Census, and by the various public utility commissions of the country. At the outset this certainly appeared to be "some stunt"!

The President of the Association subsequently appointed the following persons to serve as such committee, viz., Mr. Albert L. Sawyer, Haverhill, Mass., chairman; Mr. Walter P. Schwabe, Thompsonville, Conn.; Mr. Samuel H. MacKenzie, Southington, Conn.; Mr. Edwin L. Pride, Boston, Mass.; Mr. Alfred R. Hathaway, Springfield, Mass.

Many causes have contributed since then to prevent any tangible headway being made by your committee, although individual members have more or less been accumulating facts and material along this line for possible concentration when conditions might be favorable; and then the World War and its attendant incidental responsibilities for everybody

made it almost impracticable to meet together as a committee or to have needful conferences. As Irvin Cobb recently said, regarding certain ideas and material he wanted to use in one of his articles, the darned things wouldn't jell!

With these preliminaries out of the way we will proceed to the main subject; and your committee would call attention at this time to the following pertinent facts appearing from a study of the matter, and which in our opinion cannot be gainsaid by thinking men of to-day.

Firstly. Every water-works enterprise at the present time serving the public (both small and greater) — whether such enterprise be privately owned and operated or be municipally owned and operated — is now universally classed as a "*public utility*" (along with gas and electric lighting plants, steam and electric railroads, telephone systems, etc.), and as such should be governed by the same fundamental methods of economic operation and control as all other public utilities. The only persons pretending to disagree are the politicians and those who do not *think*.

Secondly. In nearly every one of the United States during recent years there has been created, by legislative enactment and by the will of the people served, some form of a "public utility commission," or similar body, for the purpose of exercising certain proper control and direction over its "public utilities," and for the furnishing of needed and just protection to both the utilities and to the public which they serve.

Thirdly. Many of these public utility commissions, or public service commissions, have by law formulated and prescribed uniform accounting systems and classifications of accounts for the *privately owned* and operated *water works* and other utilities under their control; and in a number of the states such uniform accounting is prescribed for and required of the *municipally owned and operated water utilities* as well. (*Why not?*)

To the question as to the need of uniformity and improvement in the accounting of the municipal water utilities of to-day, the following should be considered sufficient in reply.

It is known that all private water utilities are obliged to follow well-defined methods and accounting practice, in order not only to meet requirements of the various public utility commissions but to meet requirements of the stockholders (the owners) in order that their invested interests may yield proper returns and at the same time conserve and keep protected their property for future operations.

Should the ownership of such utility by a municipality be just cause for ignoring the needs and methods provided in the case of private ownership? And how does such change of owners effect any change in the status of such utilities before the public served?

In perusing the annual reports received by one *municipal water works* (something like 250, maybe) we find some sort of record of the total *cash* received and expended during the year past (in numerous kinds of classification), but rarely do we find a simple, informing *balance sheet* of assets and liabilities, and of earnings and expenditures *accrued*, so that the financial standing of that utility can be readily determined without an exhaustive investigation by trained and practical accounting experts!

Listen to this extract from comment by the editor of a prominent public-service publication in this country, in the matter of an investigation made a few years ago of a certain public utility owned and operated by one of our large western cities. He states that this plant, " while claiming profits of from $100 000 to $200 000 two or three years ago, under the limelight of an official investigation turned up a deficit of $58 000 for the year, and that excluded part of the taxes. The investigation was made by engineers employed by the administration itself. . . . When the engineers . . . made their report . . . they stated, ' The delay in rendering this report and the almost inexplicable length of time it has taken to prepare the statements herein must be entirely attributed to the chaotic conditions of the bookkeeping records.' . . ." The editor goes on to say that " the engineers gave about seventy pages in their report to corrections of errors found in the plant's records. This system of bookkeeping is not confined to . . . ; *it is common to municipal ownership, with some fine exceptions. . . .*"

Of course this was a flagrant and prominent case, but the illustration of the common need of to-day, in lesser or greater degree, is certainly present.

The coming of the various forms of income taxes, imposed by governments, has startlingly shown the small storekeeper, as well as many larger merchants, the immediate need of better accounting (or in some instances the need of *some* accounting) in order that their true income (not necessarily expressed in *cash*) may be definitely determined, and along *certain uniform lines.*

The question of need having been briefly (?) met, your committee will proceed to state that, as is now apparent, they have considered principally such an accounting scheme as is practicable for use by the *municipal water utilities especially*, but which is at the same time exactly the same as is prescribed for the privately owned water utilities, and followed by them.

In one or two instances the *titles* of certain controlling accounts may have been changed to suit the requirements of the municipal plants, for statements and reporting purposes, but they will be easily interpreted by the private plant officials in comparisons with their counterparts in the private works accounting statements. If private utilities should wish to adopt the scheme at any time (of course by permission of the state con-

trolling utility commissions) such minor changes in titles, etc., can easily be made by their accountants without in any way interfering with the integrity of the proposed system.

One of the members of your committee has in his office collected a number of printed pamphlets, showing the uniform classification of accounts which have been formulated and prescribed for water utilities by some of the different states in the country, together with the system formulated by the U. S. Bureau of the Census, and also current and bound copies of opinions being constantly handed down by the various public service commissions of the United States, which with much other matter has been available in this study. The various publications and authorities which have been consulted, and have furnished valuable material for appropriation in the outlined system herewith submitted, include the following:

Uniform Classification of Accounts for Water Utilities by Public Utility or Public Service Commissions (or their equivalent bodies) of the states of Maine (includes municipal water works), 1915; New Hampshire, 1915; Connecticut, 1914–1918; Pennsylvania (includes municipal water works), 1918; New Jersey (think it includes municipal works), 1913; Wisconsin (includes municipal works), 1908 (much quoted); Indiana (includes municipal works), 1913; California (think includes municipal works), 1913; Washington (State of) — (expressly for municipal works), 1916.

" Uniform Accounts for Systems of Water Supply " (for both municipal and private systems), issued by the Bureau of the Census, Washington, D. C., in 1911, and " Arranged by Representatives of the United States Bureau of the Census, American Water Works Association, New England Water Works Association, American Association of Public Accountants, Ohio Bureau of Uniform Public Accounting, and Others Interested."

Pamphlet entitled, " Interpretation of Water Works Accounts," by Mark Wolff, certified public accountant, New York City.

Paper on " Water Works Accounting," by Edwin L. Pride, certified public accountant, Boston, Mass. (referred to at the commencement of this report).

Public Utilities Reports, Annotated (containing decisions of the public service commissions and of state and federal courts) — (referred to above).

Journal of the New England Water Works Association.

Various other publications and technical journals, etc.

Also the accounting system and classification in use by the Municipal Water Works of Springfield, Mass., which was formulated and recommended by Mr. William J. Hagenah, of Chicago, public utility engineer and statistician and accountant (formerly connected with the Public Utility Commission of Wisconsin), which system was adopted by the Springfield Board of Water Commissioners and used since 1913. This system, by the way, was inaugurated and operated by the *same number* of office employees before connected with the works, and increases of em-

ployees thereafter were due to the natural growth of the business and not to the accounting system, which in fact made the accounting work much easier than in former years. This is especially mentioned as answering a possible objection in adopting any new system which may need more office help.

Besides the foregoing, the available accounting systems of certain private water works and other municipal water works were also consulted.

In the perusal and study of the various authorities referred to and listed above, your committee has appropriated whatever material and suggestions therein found and considered herein useful, without attempting to give credit mention of same in the outlined scheme submitted, but it will be understood that all due credit is hereby acknowledged by the committee without further detailed mention.

With the foregoing in mind, and supported by the weight of authority implied by the use of such available material and guides, your committee has appropriated what to them has seemed to be the best and simplest ideas and arrangements found in such authorities, and has formulated and submitted a simple but comprehensive *outline* for a possible scheme of *uniform accounting for water-works utilities,* — and especially for those owned and operated by municipalities, — shown by a set of *condensed and classified lists* of proposed accounts, *arranged in statement forms* for balance sheets and reports (instead of numerous accounts in the detail that may be called for in future), which by a little study will very readily indicate the manner and logical method of use.

In such arrangement of accounts it is assumed that the water utility should be a *self-supporting proposition* or enterprise of the municipality, and no provision is made for contribution of municipal funds towards its operation; but this provision can easily be taken care of by the utility's accountants if needed.

It is to be especially understood that your committee has not attempted to prescribe exact accounts or titles, forms of books and stationery, or any kinds of blanks or forms, and has entered into detail explanation of only a few of the indicated accounts or treatment of same. It is, however, thought that from a study of the scheme submitted any ordinary accountant can evolve and arrange for use a proper set of modern accounts for any water works utility with which he may be connected.

A very modest, but an expert, public accountant of long and practical experience in investigations of public utilities, and in formulating accounting systems for the same, a few years ago stated to one of the members of your committee that the real basis of all true accounting was " common sense " ; and in the committee's attempt to discharge properly its duties it has endeavored to keep this axiom ever in mind.

The accounting scheme submitted is outlined as follows:

A Condensed List and Statement Form for Income and Profit and Loss Accounts (for monthly and annual use) — (all accounts on Accrual — not Cash — Basis) — including Operating Revenues, Operating Expenses, Non-Operating Revenues, Deductions from Gross Income, Net Income, and Disposition of Net Income.

A Classified List of Income and Profit and Loss Accounts (as shown on above Condensed List) — including indicated and given explanation of these accounts, with suggested arrangement and subdivisions, all supporting condensed list.

A Condensed List of Balance Sheet Accounts (in balance form), showing Assets and Liabilities in condensed balance grouping.

A Classified List of Balance Sheet Accounts, showing Supporting Detail Accounts, with indicated or given explanations of same. *Also under Plant Accounts* is shown a possible and logical analysis of same into various physical and other units, for appraisal purposes when wanted. This analysis conforms to the different steps or processes in sequence of operation of the water utility, and corresponds to the grouping of accounts, which lends itself to the obtaining of proper data for rate and consumption questions, as well as the financial data always needed.

A Condensed Summary Form for showing Cash Receipts and Expenditures in Annual Reports, under various Funds; this is followed by a supplementary and more detailed form for use in showing funded divisions of such *cash expenditures*, where it may be wanted. Where any water utility may find it to be inexpedient to at once adopt and put into practice the suggested scheme of accounting, it may, by the use of these forms, obtain at least some uniformity for the comparison of *cash transactions* by its utility operations with the same transactions by another utility, which uniformity is also now sadly lacking. Then, whenever such utility may be in better condition to adopt the accounting system here outlined and suggested (or some other system which may be recommended by the Association), even to the extent at first of using the grouping accounts, and adding the supporting sub-accounts later, the changes will adapt themselves easily and gradually, and the cash statements can be kept as supplementary statements.

No scheme of *numbering accounts*, as is commonly used, is here submitted by your committee, as such numbering constitutes in no sense any part of the account-titles, but are used for easy reference by the accounting operators, and they may very properly be left therefore to such operators for determination as needed.

Likewise all minute definitions and instructions are here left for some possible future committee who may be appointed by your body to carry on and complete the outlined system here submitted tentatively, or to formulate and submit an entirely different system and report.

It is of course understood that the submitted scheme contemplates only the *double-entry method* of bookkeeping, and all accounting on the *accrual basis*, and not on a cash basis.

In this connection your committee desires to here record the following extract from the accounting paper before referred to, as worthy of more

absorption by all accounting operators and by water-works officials as well, viz., —

"The purposes of good accounting are to give information of the operations and reflect its financial conditions. But, in order to do this, it is necessary that the accounts show the accurate and complete record, and this can only be done by adopting the accrued basis. Recording only sums received and sums paid out, without any reference to revenue which the city would receive, or the expenditures which it would have to meet, — which would include not only amounts paid out but amounts of obligations incurred and not yet paid, — is wrong."

In closing this perhaps too-long report, your committee would wish that the membership of the Association might have an opportunity to study it in full, and be ready for later discussion of the matter at some of the winter meetings in Boston, after which some definite decision may be finally arrived at by the Association, and a modern and much-needed accounting scheme adopted and sanctioned as a standard form for use by its municipal membership, to the advantage and benefit of present and future members, and of the water-works utilities which they may represent.

With this final result in view, your committee recommends that the New England Water Works Association receive and tentatively approve this report, and order the same printed in full, for use by its members in their study and discussion at some future meetings of the Association.

Respectfully submitted,

COMMITTEE ON UNIFORM ACCOUNTING.

(Signed) ALBERT L. SAWYER, *Chairman.*
(Signed) ALFRED R. HATHAWAY.
(Signed) WALTER P. SCHWABE.
(Signed) SAMUEL H. MACKENZIE.
(Signed) EDWIN L. PRIDE.

Condensed List and Statement Form of Income and Profit and Loss Accounts.

(For Monthly and Annual Use.)

(*All Accounts on ACCRUAL — not Cash — Basis.*)

OPERATING REVENUES.

(See Classified List.)

I. — Earnings from Sales of Water to Private Consumers	$	
II. — Less Abatements, Refunds, etc.		
		$
III. — Earnings from Sales of Water to the Municipality		?

Note: If no payment is made for municipal uses of water, state estimated total value of such uses here ($........), — not to be included here in revenue total, — and give reasons for such non-payment. Classified accounts to be kept of such current uses and charges, and to be *charged off* at close of year *as a bad debt*, if no payment to be made.

IV. — Earnings from Use of Water by the Water Works Utility itself, and included in its Operating Charges and Expenses		
Total Operating Revenues (water)		$

OPERATING EXPENSES.

(See Classified List.)

V. — Source of Supply Expense	$	
VI. — Transmission Expense		
VII. — Distribution Expense		
VIII. — Commercial Expense		
IX. — General Expense		
X. — Undistributed Expense		
(Show separate total of above)	$	
XI. — Depreciation Reserve Charge		
XII. — Contingencies (extraordinary)		
XIII. — Taxes		
Total Operating Expenses		
Operating Profit		$
XIV. — Non-Operating Revenues (not water; net profit on mdse. sales, jobbing, rentals, etc.)		
Gross Income (forward)		$

DEDUCTIONS FROM GROSS INCOME.

XV. — Interest on Funded Debt (net)	$	
XVI. — Interest on Floating Debt (net)		
XVII. — Interest on Other Liabilities (net)		
XVIII. — Miscellaneous Deductions		
Total Deductions		
* Net Income		$

* *Disposition of Net Income.* — Any payments for dividends, or appropriations for same or to Municipal Funds, should here be deducted, and *Balance of Net Income* will then be carried to Surplus Account.

Classified List of Income and Profit and Loss Accounts.

(All on Accrual — not Cash — Basis.)

OPERATING REVENUES.

Earnings from Sales of Water to Private Consumers
(See page 76 for Explanation Sheet of Classification):

	Charges.	Abatements and Refunds.	Net Revenue.
Commercial Consumers (metered)	$	$	$
Commercial Consumers (unmetered)			
Industrial Consumers (metered)			
Industrial Consumers (unmetered)			
Institutional Consumers (metered)			
Institutional Consumers (unmetered)			
Sales to Contractors (metered)			
Sales to Contractors (unmetered)			
Miscellaneous Consumers (metered)			
Miscellaneous Consumers (unmetered)			
Earnings from within city (metered)	$	$	$
Earnings from within city (unmetered)			
Total	$	$	$

(Water furnished outside city, to adjacent or suburban consumers, — including any along the line of supply or transmission mains, — should be separately classified as above and shown hereunder, divided between metered and unmetered; water furnished by contract to adjacent and suburban towns or cities — either as emergency or additional or entire supplies to same, should likewise be here shown separately and classified as "Wholesale Service," divided as between metered and unmetered, also.)

The following will serve as illustration:

Commercial Sales ( ) Transmission Main	$	$	$
Commercial Sales ( ) A, B, C Tracts			
Commercial Sales ( ) Sundry Consumers			
Industrial Sales ( ) Co. or Corporation			
Wholesale Service, Town or City of (............)			
Earnings from outside city (metered)	$	$	$
Earnings from outside city (unmetered)			
Total	$	$	$
Total Earnings from Sales to Private Consumers:			
(Metered)	$	$	$
(Unmetered)			
Total, as per Items I and II, on Condensed Revenues Statements	$	$	$

Earnings from Sales of Water to the Municipality:

(The following alphabetical arrangement of the different departments or units is here suggested; each unit to show if metered or unmetered, or how amount is arrived at.)

	Items.	Totals.
Almshouse and Annexed Buildings	$	$ ....
Charities Department	....	....
Drinking Fountains and Troughs (or Tanks)	....	....
Fire Department — Buildings	....	....
Fire Department — Municipal Hydrant Service (... hydrants — average for year — at $ ... each)	....	....
Forestry Department Buildings	....	....
Highway Department Building, Shops, Yards, etc.	....	....
Municipal Office Buildings (Town or City Hall, etc.)	....	....
Park Department Buildings	....	....
Park Department — Fountains, Parks, etc.	....	....
Police Department Buildings	....	....
Public Playgrounds	....	....
Public Sanitaries	....	....
School Department Buildings	....	....
Scavenger Department Buildings, etc.	....	....
Sewer Department Buildings	....	....
Sewer Department — Flushing Purposes, etc. (state how amounts are arrived at)	....	....
Street Sprinkling and Washing (state how amount is arrived at)	....	....

(Besides subdivisions of "metered" and "unmetered" amounts, the foregoing departmental units are subject to further subdivisions and additions, as may be desirable in different towns or cities.)

Total Earnings from Sales to the Municipality, as per Item III on Condensed Revenues Statement:

	Items.	Totals.
(Metered)	$	
(Unmetered)	....	$ ....*

Earnings from Water Used by the Water Works Utility and Included in its Operating Expenses:

	Items.	Totals.
(Show where used and amounts metered and unmetered)	$	
	....	
Total, as per Item IV on Condensed Revenues Statement		$ ....

* If no cash payment is made by the municipality for this amount, state the fact here, as well as on Condensed Statement.

OPERATING EXPENSES.

Source of Supply Expense:	Operation.	Maintenance.	Totals.
(Showing following divisions) —	$	$	$ ....
Superintendence.			
Pumping System expense (if not gravity) (subdivided as to kind of power).			
Collecting System expense.			
Purification System expense.	(All items and totals		
Water Storage System expense.			
Supply Sanitation System expense.	to be distributed to		
(Each above division subdivided to show following) —	above heads and columns.)		
Operating Labor.			
Supplies and Expenses (detail accounts).			
Maintenance (repairs and upkeep) of buildings, fixtures, grounds, structures, equipment, etc. (detail accounts).			
	$	$	
Total Source of Supply Expense, as per Item V on Condensed List . .			$ ....

Transmission Expense:	Operation.	Maintenance.	Totals.
(Showing following divisions) —	$	$	$ ....
Superintendence.			
Buildings, Fixtures and Grounds expense.			
Structures and Equipment expense.			
Transmission Telephone Lines expense.	(All items and totals		
Patrolling Transmission Mains expense.			
(Each of above divisions subdivided to show following) —	to be distributed to		
Operating Labor.	above heads and columns.)		
Supplies and Expenses (detail accounts).			
Maintenance (repairs and upkeep) of buildings, fixtures, grounds, structures, and equipment, etc. (detail accounts).			
	$	$	
Total Transmission Expense, as per Item VI on Condensed List . . .			$ ....

	Operation.	Maintenance.	Totals.
Distribution Expense:			
(Showing following divisions) —	$	$	$
Superintendence.			
Street Division expense.			
Meters and Fittings Division expense.			
Consumers' Premises expense.			
Dist'n Buildings, Fixtures and Grounds expense.	(All items and totals		
Distribution Structures and Equipment expense.			
Miscellaneous Distribution expense.	to be distributed to		
(Each above division to be subdivided to show following) —	above heads and columns.)		
Operating Labor.			
Supplies and Expenses (detail accounts).			
Maintenance (repairs and upkeep) of buildings, fixtures, structures, equipment, distribution mains, hydrants, gates and valves, services, meters, fountains and troughs, etc.			
	$	$	
Total Distribution Expense, as per Item VII on Condensed List . . .			$

Commercial Expense:

Commercial Division Salaries	$
Commercial Division Supplies and Expenses	
Reading Meters Salaries	
Reading Meters Supplies and Expenses	
Miscellaneous Commercial Expenses	
Undistributable Inspection Expenses	
Total Commercial Expense, as per Item VIII on Condensed List . . .	$

	Operation.	Maintenance.	Totals.
General Expense:			
Salaries of Officers and Assistants.	$	$	$
Salaries of General Office Clerks.	(All items and totals		
General Office Supplies and Expenses.			
General Law and Legislative Expenses.	to be distributed as		
Maintenance of General Office Structures.			
Maintenance of General Office Equipment.	described above.)		
	$	$	
Total General Expense, as per Item IX on Condensed List			$

Undistributed Expenses:

Injuries and Damages	$
Utility Equipment Expense, Automobiles	
Utility Equipment Expense, Teams	
Insurance Expense	
Stock and Stores Expense	
Shop Expense	
Pensions and Relief Expense	
Suburban Supplies Expense	
Miscellaneous Expense	
Inventory Adjustments (debit or credit)	
Total Undistributed Expense, as per Item X on Condensed List . . .	$

Depreciation Reserve Charge:

This operating account (as well as the "Depreciation Reserve" account under Liabilities) is prescribed by all public-utility commissions and accounting authorities of the present day; is insisted upon for all privately owned utilities by controlling commissions (and for municipally owned utilities by such commissions in certain states); and should be carried by all municipally owned utilities as a needed element in proper accounting.

This account should be *charged periodically* (monthly suggested) a proportional amount of the estimated annual depreciation of the capital tangible property in service of the utility, which annual depreciation shall be estimated to cover the cost of future replacements of tangible property, made and to be made necessary on account of gradual wear and tear and obsolescence and inadequacy during the life of such property. It is recommended that, in determining such depreciation, an annual schedule be maintained, showing the various physical units of tangible property in accordance with the classified list of same under "Assets" (herewith accompanying), and with estimated depreciation of each unit shown on the percentage basis.

The effect of thus carrying proportional charges into annual "Operating Expenses" is the distribution of the burden of such certain costs throughout the years of service of such property.

The cost of hand and other small portable tools is not chargeable to this account, but are included in and charged to the operating expenses of the year in which they are purchased.

All amounts *charged* to this account shall be *credited* at the same time to the "Depreciation Reserve" account, under Liabilities, as therein described; and the cost of all unit renewals and replacements shall be charged to the latter account and not to this account.

Total Depreciation Reserve Charge, as per Item XI on Condensed List $

Contingencies (Extraordinary):

When the property of the utility is visited by an extraordinary casualty of such a nature as to be beyond anticipation through the exercise of ordinary and reasonable prudence, and of such a nature as not to be contained in the provisions for depreciation (as earthquakes, floods, cyclones, etc.), resulting in irreparable damage, there may be charged to this account the original cash cost of such irreparable damaged property, less the salvage or scrap value and irreparable wear and tear from use accrued thereto. When the amount of such damage or loss is considerable, there may be set up an *Extraordinary Casualties Suspense Account*, to which may be credited monthly the amount charged to the account *Contingencies (Extraordinary)* until the total loss or damage caused by such casualty shall be wiped out through operating expenses.

Total Contingencies (Extraordinary), as per Item XII on Condensed List . . . . $

Taxes:

Charge to this account the amount paid or accrued for taxes of every description, including taxes on poles, real estate, buildings, capital stock or equity, franchises, gross receipts, easements, and federal taxes.

Total Taxes, as per Item XIII on Condensed List . . . . $

NON-OPERATING REVENUES.

Net profit on sales of products (wood, sand, hay, etc.), merchandise sales, jobbing, and other work, rentals of land, buildings, etc., — classified separately for ready reference.

Total Non-Operating Revenues, as per Item XIV on Condensed List . $

DEDUCTIONS FROM GROSS INCOME.

Classify separately net amounts of interest for each class and issue of bonds and other obligations, and also amounts of other deductions, as indicated in condensed list.

Total Deductions from Gross Income, as per Items XV, XVI, XVII, XVIII, on Condensed List . . . . $

Condensed Balance Sheet Accounts. For Self-Supporting Water-Works Utility.

(*All Accounts on Accrual — not Cash — Basis.*)

ASSETS.*

XIX. — Plant, Property and Equipment (Cost Basis), ... 192 (aggregate at date of new accounting)		$ ....
XX. — Additions to Plant, Property and Equipment (Cost Basis) since .... 192 (since new accounting)		.....
(Showing total cost to date)		$ ....
XXI. — Stock and Stores		....
XXII. — Accounts Receivable		....
XXIII. — Cash (General Current Funds)		....
XXIV. — Cash (Special Funds)		....
XXV. — Sinking Funds		....
XXVI. — Miscellaneous Current Assets		....
Total Assets		$ ....

LIABILITIES.*

XXVII. — City (or Town) of .... Equity (Capital Investment Account)		$ ....
XXVIII. — Funded Debt (Bonded Obligations)		....
XXIX. — Mortgage Liabilities		....
XXX. — Current Liabilities		....
XXXI. — Accrued Liabilities		....
XXXII. — Depreciation Reserve		....
XXXIII. — Other Reserves		....
XXXIV. — Surplus (Unappropriated)		....
Total Liabilities		$ ....

Classified Lists of Balance Sheet Accounts. Showing Supporting Detail Accounts as Suggested Thereunder.

(*For Current Annual Use.*)

ASSETS.

XIX.— *Plant, Property and Equipment* (*Cost Basis*),............ 192.... (*as per Condensed List*).

(Aggregate of all property acquired or installed prior to adoption of new accounting system, and to be shown as separate total until such time as an appraisal and physical classification may be made of same, for *merging* with subsequent additions which may have been properly classified under the new accounting system.)

XX. — *Additions to Plant, Property and Equipment* (*Cost Basis*) *since* ....192.... (*as per Condensed List*).

(Aggregate of all property acquired or installed subsequent to adoption of new accounting system, and to be annually shown as a separate cumulative total until such time as a merged appraisal and physical classification of the entire plant and property may be made.)

The following is a suggested *Classifications of Plant and Property Accounts*, as logically needed in both the appraisal and the operation until such appraisal may be

* See *Classified Lists* of Assets and Liabilities Accounts, following.

made. Such classification can be immediately used upon adoption of the accounting system, for all operations thereafter.

Intangible Property.

Should include:

1. — Organization Costs.
2. — Franchises, Rights, and Licenses.
3. — Other Intangible Property.

Tangible Property.

Should include:

1. — *Lands Used in Operation (subdivided as follows):*
    - *a* — Pumping Station Land.
    - *b* — Source of Supply and Collecting System Land.
    - *c* — Purification System Land.
    - *d* — Water Storage Land.
    - *e* — Supply Transmission Land.
    - *f* — Distribution System Land.
    - *g* — Stores Department Land.
    - *h* — Utility Equipment Land.
    - *i* — General Office Land.
    - *j* — Other Lands Devoted to Operation.
2. — *Buildings, Fixtures, and Grounds (subdivided as follows):*
    - *a* — Pumping Station, Buildings Fixtures, and Grounds.
      (Separate accounts for Steam Power, Hydraulic Power, Electric Power, Gas Power, etc.)
    - *b* — Source of Supply and Collecting System B., F., and G.
    - *c* — Purification System B., F., and G.
    - *d* — Water Storage B., F., and G.
    - *e* — Supply Transmission B., F., and G.
    - *f* — Distribution System B., F., and G.
    - *g* — Stores Department B., F., and G.
    - *h* — Utility Equipment B., F., and G.
    - *i* — General Office Equipment B., F., and G.
    - *j* — Other B., F., and G. devoted to Operation.
3. — *Structures and Equipment Used in Operation (subdivided as follows):*
    - *a* — Pumping Stations Equipment.
      (Separate accounts for Steam Power, Hydraulic Power, Electric Power, Gas Power, etc.)
    - *b* — Source of Supply and Collecting System Structures and Equipment.
      (Separate accounts for Collecting Aqueducts, Dams, Intakes, Supply Mains, etc.)
    - *c* — Purification System Structures and Equipment.
    - *d* — Water Storage Structures and Equipment.
    - *e* — Supply Transmission Mains.
    - *f* — Supply Transmission Telephone Lines and Equipment.
    - *g* — Distribution System Structures and Equipment.
      (Separate accounts for Distribution Mains, Hydrants, Services, Meters, Fire Cisterns, Basins, Fountains and Troughs, Distribution Telephone Lines and Equipment, etc.)
    - *h* — Stores Department Equipment.
    - *i* — Utility Equipment.
    - *j* — General Shop Equipment and Tools.
    - *k* — General Office Equipment.
    - *l* — Miscellaneous Equipment.

4. — Miscellaneous Construction and Equipment Expenditures (during construction and before operation):

a — Engineering and Superintendence.
b — Salaries.
c — Office Supplies and Expenses.
d — Stationery and Printing.
e — Law Expenses.
f — Injuries and Damages.
g — Insurance.
h — Taxes.
i — Interest.
j — Discount on Bonds.
k — Miscellaneous Construction Expenses (not includable above).
l — Unfinished Plant Investment (current account only).
m— Property in Other Departments (devoted to other than water operations).
n — Cost of Plant Purchased (in lieu of construction).

5. — Investments.

To include properties acquired not for use in present operations, but for proper control over other property in the utility service, or for devotion to future operations.

Appropriate subdivisions of this account should be made to keep separate the different classes or units of such investments.

XXI. — *Stock and Stores (per annual inventories and current changes):**

Main Pipe Stock (including fittings, hydrants, gates, etc.)		$ ......
Service Pipe Stock (including fittings and appurtenances)		
Meter Stock (including fittings and appurtenances)		
Small Tools Stock (hand tools, etc.)		..
Miscellaneous Stores and Supplies (not includable elsewhere)		
Engineering Supplies		
General Office Supplies		
		$ ..
Collecting System Supplies	$	
Pumping System Supplies		
Purification System Supplies		
		...
* Total Stock and Stores		$ .....

XXII. — *Accounts Receivable.*

To include all amounts on open accounts due the water works utility from consumers and other parties.

XXIII — XXIV. — *Cash Accounts.*

General revenue funds should be kept entirely separate from any special funds, and the latter may be subdivided into as many accounts as may be deemed desirable.

XXV. — *Sinking Funds.*

To include all funds set apart or deposited with trustees, for the purpose of redemption of outstanding bonds and similar debt obligations, together with all income derived from such funds. Should be subdivided into separate accounts for each separate sinking fund.

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* Inventories should be taken periodically, at least as often as once a year, and differences investigated and cleared. Above subdivisions are optional and changeable, but will greatly assist in locating shortages and overages disclosed by inventories and to be disposed of through proper adjustment accounts.

XXVI. — *Miscellaneous Current Assets.*

To include cost of current assets not includable under any of those already defined.

LIABILITIES.

XXVII. — *City (or Town) of.. ... .Equity.*

For municipally owned water-works utilities this account is especially recommended in place of *Capital Account*, or *Capital Stock Account*, and as better representing by title the owners' growing equity or paid-up interest in the utility investment. This account should be set up as of date when new accounting system may be adopted, to include all accruals of this nature to such date. And thereafter all costs for construction or property paid for from earnings, and amount of all construction bonds or other similar debt obligations retired or canceled by payments from earnings or from funds derived from earnings, should be credited or transferred to this account from the surplus account.

XXVIII. — *Funded Debt (bonded obligations).*

A separate account should be set up and kept for each different issue and class of bond obligation.

XXIX. — *Mortgage Obligations.*

To include all mortgage liabilities or obligations except such as are evidenced by bonds. Separate accounts should be set up and kept for the different classes of such obligations.

XXX. — *Current Liabilities.*

To include the following accounts, viz., Accounts Payable, Consumers' Deposits, Matured Interest Unpaid, Miscellaneous Current Obligations.

XXXI. — *Accrued Liabilities.*

To include the following accounts, viz., Unmatured Interest Account, Unmatured Insurance Account, Unmatured Taxes Account, Miscellaneous Liabilities Accrued.

XXXII. — *Depreciation Reserve.*

To this account shall be *credited* monthly — or as often as they are made — all charges to *Operating Expenses* under "Depreciation Reserve Charge" account, as thereunder described; together with any income derived from the depreciation reserve fund (if such *fund* is established), and any appropriations which may be made to it.

When any building, structure, transmission, or distribution main, facility or unit of equipment, originally charged to capital assets and included in tangible property, becomes through wear and tear in service economically irreparable, the substitute therefor (having substantially no greater capacity than the unit for which it is substituted) shall be *charged* to this account.*

The salvage or scrap value of any unit of equipment retired from service or replaced by another unit should be *credited* to this account.

XXXIII. — *Other Reserves.*

For any other reserves, including any temporary or optional reserves, not elsewhere provided for.

XXXIV. — *Surplus Account (balance unappropriated).*

This account will include all collective amounts of *annual net income balances*, less amounts transferred to the "City of........................Equity Account," as thereunder described.

At the close of each fiscal yearly period the surplus balance will represent the amount by which the assets exceed the liabilities.

Note. Should the annual operation of the water-works utility result in a *continued net loss*, then the cumulative totals of such net losses would appear as a *deficit account* on the debit side of the balance sheet, under Assets, and would represent the amount by which the liabilities exceeded the assets.

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* For the purpose of segregation and future ready reference, it is recommended that the cost of all renewals and replacements of capital property be first charged to a current "*Renewals Account*," which will then be annually closed into the Depreciation Reserve account as one total annual amount.

Condensed Summary of Cash Receipts and Expenditures, during 192 ..
(For Annual Reports.)

Items.*	Water-Works Revenues.	Bond and Loan Funds.	Special Funds.	Totals.
Receipts — 192..				
Collections of Revenues, —				
Water Sales (operating)	$			$
Misc. Sales (non-operating)				
Unclaimed Wages (years of.............)				
Refunds (sundry accounts)				
Proceeds from Bond Sales and Loans		$		
Other Receipts (miscellaneous)	?		?	
Total Receipts, Current Year	$	$	$	$
Transfers (+ or —) (if any)	?	?	?	
Balances Forward from Prior Year	?	?	?	?
Total Receipts and Balances, 192 ..	$	$	$	$
Expenditures — 192..				
Bills Approved and Paid	$	$	$	$
Pay-rolls Approved and Paid				
Interest Paid on Bonds				
Interest Paid on Loans				
Bonds Due and Paid				
Loans Due and Repaid				
Bond Sinking Funds				
Appropriations and Reserves				
Total Expenditures, Current Year	$	$	$	$
Balances Forward to Next Year	?	?	?	?
Total Expenditures and Balances, 192.	$	$	$	$

* See *Division* of Cash *Expenditures*, following.

Division of Cash Expenditures — 192

(For Annual Reports.)

FROM WATER-WORKS REVENUES.

Operating Expenses (not including Depreciation Reserve Charges):

Total, as per Income and Profit and Loss Account . . . . . $

Less amounts included, not Cash . . . .

$

Construction (Additions to Plant and Property):

Intangible Property	Cost charges, — less amounts not cash, — under groups here shown, and by items as per classified lists elsewhere given.
Lands and Easements	
Buildings, Fixtures, and Grounds	
Structures and Equipment	
Miscellaneous Construction Equipment	

Renewals and Replacements (of Plant and Property):

Including Buildings, Fixtures and Grounds, Structures and Equipment; Transmission Mains, Distribution Mains, Hydrants, Gates, Services, Meters in Service, Utility Equipment; and all other tangible property used in operation, subject to depreciation. (The total costs of such expenditures are those chargeable to Depreciation Reserve Account, and includable in estimated amount of "Depreciation Reserve Charge" as debited to current Operating Expenses, and as shown elsewhere).	Cost charges, — less amounts not cash, — under groups and accounts by items as per classified lists given elsewhere.

Cost of Miscellaneous Sales, — Non-Operating Revenue Accounts:

Costs of Labor and Material charged consumers, Jobbing, Rentals, etc. (net) . . . .

Stock and Stores Increase or Decrease during Current Year:

Plus or minus cost difference shown in such account . . . .

Miscellaneous and Cost Adjustment Accounts (net) . . . .

Total Approved Bills and Pay-rolls Paid (from revenue), (as per Cash Summary Statement) . . . . $

Interest Payments (net total) . . . . $

Bond and Loan Payments (net total) . . . .

Sinking Fund Payments (net total) . . . .

Total Debt Requirements . . . .

Total Cash Expenditures (as per condensed cash summary) . . . . $

Appropriations and Reserves (cash transfers) . . . .

Total Cash Payments from 192 Revenues (per cash summary) . . . $

(In similar manner itemize cash expenditures from Bond and Loan Funds and from Special Funds, to agree with such totals in cash summary statement.)

Explanation Sheet of Classification of Earnings from Sales of Water to Private Consumers.

(Public Uses — by Municipalities — indicated on page 65.)

The following divisions and accounts (not shown elsewhere in the classified lists of accounts) are suggested for purposes of ready reference and comparisons by one water-works utility with another, and are in agreement with those adopted and recommended by the N. E. W. W. A. for use in its "Summary of Statistics" for annual reports. They will also be found useful for other statistical purposes in connection with studies of rates and consumption questions, etc.

	Code.*
Domestic. — To include only residences, dwellings, tenements, apartment blocks, flats, etc.; also hotels and boarding-houses where there are no predominant strictly commercial uses.	D
Domestic and Commercial. — To include (as one combination class) *only* premises where stores, offices, shops, or any business uses, or commercial uses (not industrial), are located in *same building* with residences, tenements, apartments, hotels, etc., and all supplied or billed as one and the same service.	DC
Commercial. — To include stores, office buildings, saloons, retail commercial establishments, theaters, etc.; also where *some* manufacturing or industrial uses are found in combination with such commercial, *if the commercial service is the principal and predominating one.*	C
Churches. — To include all uses by churches and affiliated buildings, etc.	CH

The following are the commonly suggested divisions for *Accounting* purposes, as prescribed by different Public Utility Commissions, etc., and as shown elsewhere in the suggested classified lists of accounts.

Commercial. — To include the *foregoing four divisions*, as described above.	C
Industrial. — To include only premises used *exclusively* for manufacturing or industrial purposes; such as railroads, breweries, bottling works, laundries, factories, warehouses, foundries, gas works, etc.; also where *some* commercial service is found in combination with the industrial, *if the industrial service is the principal and predominating one.*	I
Institutional. — To include such premises and uses as city libraries, art museums, science buildings, courthouses, registry buildings, government buildings, jails, truancy and reform buildings, hospitals, cemeteries, nurseries, private schools and academies, colleges and universities, armories, Y. M. C. A. and Y. W. C. A. buildings, etc.	INST
(This is a distinct division recently adopted by one of our leading authorities in prescribing a new accounting system for a New England city, and is worthy of general use.)	
Builders' Use. — To include all uses by builders and contractors.	BU
Unclassified. — To include all *miscellaneous uses* not classified above, such as for circuses and other temporary uses.	MISC

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* The code letters shown above will be found useful in embossing on addressing plates and printing on bills, and for reference use on any statements and classification sheets in current work. Special code letters can be adopted for uses supplied outside of city, with account numbers for same.

ANNUAL MEETING.

Address of Mr. Henry V. Macksey, President N. E. W. W. Association, 1920.

Gentlemen of the New England Water Works Association, — To-day the present officers complete the work of the year and turn over to their successors the duties and responsibilities which you have placed upon them.

The work of the past year has been uneventful. The meetings have been well attended, the papers presented of value fully equal to that of preceding years, and the convention was very successful, the attendance being all that could be expected and the interest shown by the members in taking part in discussion of papers presented being greater than usual.

The entertainment provided by the people of Holyoke and by the Manufacturers' Association was more attractive even than that at previous conventions.

The Association is in a sound condition financially, even though we were forced to draw upon our reserve fund to pay for the roster of the Engineer Regiment, which we felt was money well expended, and to pay for an issue of the 1919 Journal which was overdue when the present administration took charge.

The cost of living has increased for the Association as well as for its members, and in order to meet it an increase in dues became necessary. Your officers felt that, no matter what the Journal cost, no valuable material should be refused publication, and in spite of the tremendous increase in cost of paper and printing it is of as good quality as heretofore.

To avoid increased cost to the members personally, the meeting and dining place has been changed. Your dinners are as satisfactory as before, but, unfortunately, the dining room is not as well adapted for the display of pictures upon the screen as the room we have occupied in the past. It is possible that in the near future we may be able to make some better arrangement without making the cost prohibitive.

We have lost a few members through death, and quite a few through resignation and being dropped on account of dues. The Secretary will give you the details, so that I will merely say that our net loss is 20 active and 7 associate members, and that makes it evident that we must soon start a very active campaign to increase the number of members in both classes.

The retiring officers desire to thank the members for their loyal support through the past year. [*Applause.*]

Address of Charles W. Sherman, President-Elect, 1921.

Mr. President and Friends,— I have not prepared any set speech — I do not believe you care particularly to listen to one, anyway — and if you did I have no specific program or budget or anything else for the year to announce, different from that of the earlier years.

I am one of those who believe very earnestly in this Association, its place and its work, and having that belief I esteem the presidency of it as a high honor, and appreciate it accordingly. I know that the associates you have given me on the Executive Committee will work earnestly to keep up the good record which our predecessors have maintained, and with the assistance of the "steering committee," as perhaps I may call it, which you have just authorized, I hope that we may be able to present for your attention a better coördinated, if not more valuable, program of papers than it has previously been possible to obtain. Certainly the existence of such a committee offers great possibilities in so coördinating and laying out the program for the year.

One point which is brought forcibly to my attention by the failure to receive any committee reports to-day, in spite of the long list printed in the notice of the meeting, suggests a little more careful consideration of the working of committees than perhaps has been the case in the last few years. Up to a year ago there was every excuse for the practical abandonment of committee work during the progress of the war, and it became the practice during that time almost to forget that there were committees, — certainly to forget to expect reports from them, and perhaps that experience had continued to govern the committees somewhat in their recent action — or inaction, perhaps I might better say. I am a member of one or two of those committees myself, so that I feel no particular hesitation in using such terms. Nevertheless, the record of the Association in the past has been attained in large measure from the excellence of its committee work, and we cannot afford to let it fall down. The committees must be revived, if they are worth reviving, and, if not, discontinued.

Some of the committees, I know, have programs which involve work that can't well be rounded up in a single year, or sometimes in three or four years. They involve a campaign of education or its equivalent which requires a long period for its ultimate conclusion, and I believe it would be unfortunate to provide, as is done in many societies, that all committees shall expire at the annual meeting unless reappointed. Of course we could reappoint them, but I believe it more advantageous as a general practice that the membership should be continued without the formality of reappointment if the committee is worth while and, as a whole, doing good work. But I do not think it is wise to let them drift along, as perhaps has been the case with some of them.

Another thing that is forcibly brought to our attention particularly by the loss in membership is, not only that we need new members but that we need more young members. I have been holding office, off and, on in this Association for the last twenty-two years; I was a good deal younger man when I started in doing that than I am now. It seems to me as though a very much larger number of my contemporaries at the time I started are now holding office than those who are of the age that I was at that time, and I believe that it would be decidedly to the advantage of the Association if we had more young blood in the membership and taking a more active part in the work. I hope that the members, as far as they can, will get new membership and will urge the younger men to have a more active interest in the work of the Association.

I know that in many cases some of our younger members feel that their time is not available for attendance at afternoon meetings. To a certain extent that feeling may be warranted, although I think in a good many cases if the younger members would call the attention of their superiors to the conditions they would have little difficulty in obtaining permission to absent themselves for these meetings. Certainly I believe that an employer usually receives more than the value of the lost time by permitting his assistants to attend such meetings as ours.

Again I thank you for the election. [*Applause.*]

Report of Secretary.

January 3, 1921.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 872, constituted as follows: 14 Honorary, 788 Active, and 70 Associate Members, there being a net loss for the year of 27. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1920.	Honorary Members	12				
	Transferred from Members	2				
		—				14
January 1, 1920.	Total Members			810		
	Withdrawals:					
	Resigned	39				
	Dropped	20				
	Died	6				
		—	65			
	Transferred to Honorary Members		2			
			—	67		
				—	743	

	Initiations:				
	January	3			
	February	3			
	March	5			
	September	23			
	November	6			
	December	2			
		—		42	
	Reinstated:				
	Member dropped in 1914	1			
	Elected in 1919, qualified 1920	2			
		—		3	
				—	788
January 1, 1920.	Total Associates		77		
	Withdrawals:				
	Resigned	7			
	Dropped	2			
		—	9		
			—	68	
	Initiations:				
	September	2		2	
		—		—	70
January 1, 1921.	Total membership				872
January 1, 1920.	Total membership				899
	Net loss				27

Receipts for 1920.

Initiation fees			$214.00
Annual dues:			
Members	$3 192.61		
Associates	1 365.00		
		$4 557.61	
Fractional dues:			
Members	$39.00		
Associates	10.00		
		49.00	
Past dues		4.00	
Total dues			4 610.61
Advertising			3 198.76
Subscriptions			313.00
JOURNALS sold			2 394.05
Sundries			614.06
Total receipts			$11 344.48

There is due the Association:

Advertisements	$90.25
JOURNAL	1.00
Reprints	43.94
Standard Specifications for C. I. Pipe	25.00
Total	$160.19

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

REPORT OF TREASURER.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$288.96
Initiation fees	$214.00	
Dues	4 610.61	
Total received from members		4 824.61
JOURNAL:		
Advertisements	$3 198.76	
Subscriptions	313.00	
JOURNALS	2 394.05	
Sale of reprints	68.25	
Total received from JOURNAL		5 974.06
Miscellaneous:		
Sale of " Pipe Specifications "	$6.00	
Dinners	411.00	
Certificates of membership	13.50	
Button	1.00	
Meter rate sheets	5.10	
June excursion	45.35	
Membership lists	11.00	
Willard Kent testimonial	38.93	
Index	1.00	
Total miscellaneous receipts		532.88
Total receipts		$11 620.51

Expenditures.

Journal:		
Advertising agent's commission	$251.95	
Printing	9 125.09	
Editor's salary	300.00	
Editor's expense	47.79	
Reporting	296.22	
Reprints	592.25	
Envelopes and postage	83.43	
Advertising refund	14.00	
		$10 710.73
Office:		
Secretary's salary	$200.00	
Assistant Secretary's salary	1 080.00	
Assistant Secretary's expense	124.55	
Rent	600.00	
Printing, stationery, postage	322.22	
Telephone	15.56	
Miscellaneous	13.75	
		2 356.08
Meetings and Committees:		
Stereopticon	$10.00	
Dinners	423.60	
Music	5.00	
Printing, stationery, and postage	245.80	
Badges	65.00	
Traveling expenses	150.49	
		899.89
Miscellaneous:		
Treasurer's salary and bond	$67.50	
Certificates of membership	4.30	
Dues refunded	4.00	
Standard Specifications	43.95	
W. Kent testimonial	20.33	
Income tax	7.59	
Miscellaneous	6.50	
		154.17
		$14 120.87

Report of Auditing Committee.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand, as submitted in the above report.

GEORGE H. FINNERAN,
GEO. A. CARPENTER,
FRANK A. MARSTON,
Finance Committee.

LEWIS M. BANCROFT, *Treasurer*,
In account with the New England Water Works Association.

RECEIPTS.

1920.			
Jan. 1.	Balance on hand		$3 945.53
	Received of F. J. Gifford, Secretary		11 344.48
	Interest on bonds and deposits		266.03
			$15 556.04

EXPENDITURES.

Bills paid		$14 120.87
BALANCE ON HAND.		
People's Savings Bank	$1 000.00	
Mechanics Savings Bank	183.54	
First National Savings Bank	186.85	
Liberty Trust Co.	64.78	1 435.17
		$15 556.04

ASSETS AND LIABILITIES.

ASSETS.

Cash balance in banks		$1 535.17
Bonds Nos. 2642 and 2644 Lake Shore & Michigan Southern R. R. 4s, due 5–1–1931.		1 815.00
Accounts receivable:		
Advertising	$90.25	
JOURNAL	1.00	
Reprints	43.94	
Pipe specifications	25.00	160.19
		$3 510.36

LIABILITIES.

Surplus	$3 510.36
	$3 510.36

BOSTON, January 10, 1921.

LEWIS M. BANCROFT, *Treasurer.*

Report of Editor.

January 18, 1921.

The Editor submits the following report for 1920, covering Volume XXXIV of the Journal.

The report does not give the receipts and expenditures of the calendar year, which have been stated in the report of the Treasurer, but aims to furnish the total cost and receipts of Volume XXXIV.

The accompanying tabulated statements show, in detail, amount of material in the Journal.

Size of Volume. — The volume contains 520 pages, a decrease of 206 pages from that of 1919.

Reprints. — Twenty-five reprints of papers have been furnished to each author without charge.

Circulation. — The present circulation of the Journal is:

Members, all grades	872
Subscribers	84
Exchange	14
Total	970

a decrease of 32 from the preceding year. Journals have been sent to all advertisers.

Advertisements. — There has been an average of 31 pages of paid advertisements, with an income of $2 759.35, an increase over last year of $895.60. The gain is largely due to increase in rates for advertising.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $25.00 have been sold. The net gain up to a year ago had been $297.10, so that the total net gain from this source to date is $322.10, and 149 copies of specifications on hand worth $37.25 if sold at retail.

The Association has a credit of 28c. at the Boston Post-Office, being the balance of money deposited for payment of postage upon Journal at pound rates. The following tables are for Volume XXXIV, not for the calendar year. The *receipts* and *expenditures* show total charges and accounts payable, with no reference to amounts actually received or disbursed.

TABLE 1.

Statement of Material in Volume XXXIV, Journal of the New England Water Works Association, 1920.

Date	Pages of								
	Papers.	Proceedings.	Total Text.	Index.	Advertisement.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
March	66	24	90	0	33	4	2	129	33
June	45	3	48	0	35	4	...	87	5
September	78	21	99	0	36	4	...	139	7
December	114	8	122	3	36	4	...	165	11
Total	303	56	359	3	140	16	2	520	56

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXXIII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1920.

Receipts.		*Expenditures.*	
Advertisements	$2 759.35	Printing JOURNAL and mailing	$3 352.58
Sale of JOURNALS	98.25	Printing and preparing illustrations	345.02
Sale of reprints	112.19	Editor's salary	300.00
Subscriptions	313.00	Editor's incidentals	11.96
JOURNAL Index	1.00	Advertising agent's salary and commission	188.00
Meter rate specifications	5.10	Reporting	296.22
	$3 288.89	Reprinting	517.25
Net cost of JOURNAL	1 722.14		
	$5 011.03		$5 011.03

During the past year we have published the history of the 26th Engineers Regiment, the water-supply regiment of the American Expeditionary Forces in France. This history was made a second section of the December, 1919, JOURNAL and was sent to the members of the Association under the regular cover of the JOURNAL, and without the general roster; 1 650 copies in a special cover were furnished the regiment.

Appreciation is due the advertisers who cordially accepted the double 1919 rates which were made for this issue, and assisted the Association substantially in carrying out this patriotic project.

The following is financial statement of publishing history:

Cost.		
Printer's bill for printing and mailing		$4 137.58
Extra postage		24.08
Commissions on advertisements		88.75
Editor's expense		1.00
		$4 251.41
Income.		
Cash from fund subscribed to regiment	$2 296.80	
Advertising	707.50	3 004.30
		$1 247.11
* Credit for yearly index		45.05
Total net cost to the Association of 26th Engineers Regiment history		$1 202.06

Respectfully submitted,

HENRY A. SYMONDS, *Editor.*

* The cost of index should properly be added to the reported cost of Vol. XXXIII.

TABLE 3.

COMPARISON BETWEEN VOLUMES XXIV TO XXXIV, INCLUSIVE (OMITTING VOLUME XXXI), NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXIV. 1910.	Vol. XXV. 1911.	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.
Average edition (copies printed)	1 150	1 000	1 000	1 000	1 050	1 325	1 500	1 388	1 200	1 150
Average membership	732	752	740	745	803	904	1 002	954	902	885
Circulation at end of year	827	840	826	858	951	1 079	1 155	1 010	1 002	970
Pages of text	643	475	401	554	564	596	538	398	566	359
Pages of text per 1 000 members	880	632	542	746	702	659	538	417	627	406
Total pages, all kinds	808	654	567	733	719	776	707	557	726	520
Total pages per 1 000 members	1 090	870	766	984	895	859	707	584	805	588
GROSS COST:										
Total	$3 490.81	$2 625.87	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03
Per page	4.32	4.02	4.37	4.89	4.65	5.47	4.79	5.59	6.84	9.64
Per member	4.78	3.50	3.35	1.81	4.17	4.68	3.38	3.26	5.51	5.66
Per member per 1 000 pages	5.90	4.09	5.90	6.46	5.80	6.02	4.79	5.85	7.59	10.88
Per member per 1 000 pages text	7.44	7.36	8.35	8.68	7.39	7.85	6.30	8.19	9.74	15.77
NET COST:										
Total	$1 334.06	$352.82	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98	$694.50	$2 675.04	$1 722.14
Per page	1.65	.51	.17	1.80	1.61	2.70	1.65	1.25	3.68	3.31
Per member	1.82	.47	.13	1.78	1.44	2.32	1.17	.73	2.97	1.95
Per member per 1 000 pages	2.25	.55	.23	2.42	2.00	2.98	1.65	1.31	4.09	3.75
Per member per 1 000 pages text	2.83	.98	.33	2.38	2.55	3.88	2.17	1.83	5.25	5.43

Report of Tellers.

Whole number of ballots	323
Blank	4

President.

Charles W. Sherman	315

Vice-Presidents.

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Percy R. Sanders	315
William W. Brush	315
Reeves J. Newsom	313
Patrick Gear	311
George A. Carpenter	312
Scattering	3

Secretary.

Frank J. Gifford	316
Scattering	0

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Lewis M. Bancroft	317

Editor.

Henry A. Symonds	316
Scattering	1

Advertising Agent.

Henry A. Symonds	315
Scattering	1

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James A. Newlands	315
Arthur E. Blackmer	315
Scattering	1

Finance Committee.

George H. Finneran	312
A. R. Hathaway	316
Frank A. Marston	316
Scattering	2

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E. J. LOONEY,
FRED L. CUSHING,
Committee.

FREDERICK W. GOW.

Frederick W. Gow, a member of this Association, died July 28, 1920, after more than two months' illness, suffering acutely.

Mr. Gow was the second son of Robert M. Gow, an earlier member of this Association. He was born at Charlestown, Mass., August 15, 1864, going to Medford, Mass., when a small boy, when his father was appointed superintendent of the water works there in 1871. After attending the public schools at Medford he became an engraver. Leaving that occupation he became acting superintendent of the water works with his father.

Upon the death of his father he was made superintendent in 1892, holding the position until May, 1905, when he resigned to associate himself with his brother in the Charles R. Gow Construction Company. With him he had charge of some of the best and largest water-filter plants in the state, as well as working on other water-works problems, doing a general contracting business.

He married, January 17, 1889, Miss Ella F. Davenport, of Medford, Mass., who survives him with three daughters, Miss Miriam Davenport Gow, a teacher of elocution; Miss Ruth Madeline, a teacher in the Norwood High School; Miss Doris Mary, a teacher in the Medford Junior High School; and one son, Frederick William Gow, a student at Tufts Engineering School.

He is survived by two brothers, Robert C., of Cambridge, and Col. Charles R. Gow, the well-known engineer of Boston.

Being brought up in the water works with his father, the superintendent at Medford for twenty-two years, and following him for thirteen years in the same position, his home city felt it must retain his valuable and intimate knowledge if possible, so appointed him a commissioner, a position he held until his resignation in April, 1915, — most of the time as chairman.

He was a devoted member of the Elks, serving in the highest offices of his home lodge, of which he was a charter member, and a lifelong member of the Church of the Immaculate Conception.

The Association loses a valuable and conscientious fellow-member, and will miss his cheery disposition, as his home city and all who came in contact with him do.

Mr. Gow was elected a member of the New England Water Works Association June 13, 1890, a Vice-President 1905–1906, and a member of the finance committee 1914.

Fred L. Cushing,
Robert J. Thomas,
Frank E. Merrill,
Committee.

HARRY H. KINSEY.

Harry H. Kinsey was born in Bristol, Pa., July 10, 1862, and was the son of J. F. and Minnie Thomkins Kinsey. Mr. Kinsey died December 20, 1920, at his home in Allston, Mass.

Divine Providence has called to the Great Beyond our beloved and esteemed friend, Harry H. Kinsey, whose kindly presence and helpful service were ever with us.

Few men had more friends than he. He won them by his fine character, his thoughtfulness of others, his never-failing courtesy, and his acts in life which stamped him as one of Nature's gentlemen.

It seems as though a cloud had suddenly blotted out the sunshine.

For years he had participated in all the activities of this Association, and had rendered useful service in many capacities.

He had a smile for every occasion, and a good word for every one.

To each of us his passing is a personal loss and the cause for genuine sorrow.

He is gone, but the legacy of his life will remain, and will be held in reverent memory by those who knew him and loved him best.

A copy of this Memoir shall be made a part of the minutes of this meeting and shall be laid before the bereaved family of our departed friend, Harry H. Kinsey.

George Cassell.
Samuel Harrison.
Charles F. Glavin.

Boston, Mass.,
January 12, 1921.

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New England Water Works Association

ORGANIZED 1882.

Vol. XXXV. June, 1921. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

PIPE EXTENSION CHARGES.

BY NICHOLAS S. HILL, JR.*

[*Read March 9, 1921.*]

Mr. President and Fellow-Members of the New England Water Works Association,— It is not often that I have the pleasure of coming to your meetings in Boston, but I have prepared a little paper on a subject that I know has bothered a great many of the water-works fraternity in other parts of the country, and I thought probably it had caused some trouble to those working along the same lines in New England.

It might be well to say that I make no differentiation between municipally owned and privately owned water works so far as the economic principles of water supply are concerned. By that I mean to say that, whether a plant is publicly or privately owned, in order for that plant to succeed and to give service it is necessary that the revenues should equal the fixed charges on the plant, — that is, the interest and sinking fund charges in the case of a municipal plant, and the interest and depreciation reserve in the case of a privately owned plant, — the operating expenses and taxes.

Now, that is a basic principle — and every charge which is made for water service is based on the fundamental principle that the revenues must equal the expenses. It may be, of course, in a municipal plant, that all of the money is not taken from one pocket,— that is, from the water rates. Some of the revenues may come from water rates and some from general taxation. Under a properly devised system of charges in a private water company, some of the revenues should come from the water rates and some from taxation. That is, I mean to say, for example, that fire service revenue should come from taxation, because fire service is a property benefit and should not be assessed upon the water-taker as such. But with these minor differentiations the principle holds, and it holds in regard to pipe extensions as well as to any other element of water charges.

This subject is but a small part of the entire question of charges for public service, but it is very vexing at times to operators of water-works plants.

* Consulting Engineer, New York City, N. Y.

With the present conception of a public utility, whether publicly or privately owned, it is not fair for utilities to incur a cost which places an unfair burden upon consumers already connected with the system. The extra cost of an extension which does not pay necessarily places an unfair burden upon existing consumers. The reason for this is obvious. The utility is entitled to earn a fair return on the fair value of the property. Every extension which does not pay a fair return, therefore, must of necessity be recouped from the rates earned by the pre-existing plant. Now, every utility in a growing community is called upon continually to extend its services into new territory. A man may build a house a thousand or fifteen hundred feet from existing lines. He makes an application for the extension of a main to give him water service. The total amount which he may pay for water under the rate schedule is a drop in the bucket compared to the total revenue required to pay a fair return on the extension, for this revenue must not only include a fair return on the investment in the extension proper, depreciation on the extension proper, and the cost of maintaining the extension proper, but also that extension's proportion of the expenses of the entire property which may be fairly and reasonably chargeable to that extension. By the last I mean to say that whenever an extension has been made it becomes a part of the entire system and must bear its proportionate share of the costs of the entire system.

Now, the unfortunate part of the situation is that the accounting system of a great many water plants is not so framed that it is easy for them to allocate the general costs on the entire system to a new extension in a definite and accurate way. The problem of ascertaining the fair return on the extension proper, the taxes on the extension proper, and the depreciation on the extension proper is simple, but the allocation of a fair proportion of the gross cost on the entire system to the extension proper is not so easy.

I think the greatest stumbling block in connection with the problem of charging for extensions is that there is too great a desire for mathematical accuracy. The problem is not one of ascertaining the proper charge to the last mill. The problem is fairly to allocate costs so that the extension will pay a just and reasonable proportion of the general expenses of the plant. Whether the extension charge is 90 per cent. of what it should be or if it is 110 per cent. is immaterial, for it is almost impossible precisely to charge 100 per cent. of its proportion to the extension; but with almost any system of accounts a reasonable allocation may be made which will make the extension bear a fair proportion of the general expense.

If the rate structure of a water works is properly developed and cost is distributed between fixed or static costs and proportional costs, the problem is not so difficult. As a rule, the proportion of the so-called fixed charges on the property — that is, the proportion of the fair return, taxes and depreciation on a plant which may properly be allocated to fixed service or static costs — varies between 30 per cent. and 50 per cent.

in an average water-works plant. Similarly, the proportion of operating expenses on the entire plant chargeable to fixed service or static costs varies between 15 per cent. and 40 per cent. The total fixed service or static costs, which do not vary in proportion to the amount of service taken but remain stationary whether service is taken or not, amount to from 20 per cent. to 40 per cent. of the total cost of service in an average water works.

Boiled down to the simplest form, the charge which must be made for pipe extensions so that a water works may be reasonably reimbursed for their cost includes the following:

a. Fair return, interest, taxes and the cost of maintenance of the extension proper.

b. The extension's proportion of the gross fixed service or static fixed charges on the entire plant. The proportion of the gross fixed charges of the entire plant chargeable to fixed service or static cost, as previously stated, varies from 30 per cent. to 50 per cent. of the fair return, taxes and depreciation on the entire plant.

c. The extension's fair proportion of the fixed service or static operating expenses of the entire plant. The operating expenses chargeable to fixed service or static costs, as previously stated, vary from 15 per cent. to 40 per cent. of the operating cost of the entire plant.

It is obvious, therefore, that the first step in the determination of the fair charge for a pipe extension is to ascertain the cost per lineal foot of such an extension. Some water works prefer to use average prices for every extension of the same size and to base their charge per foot of the extension proper on that average cost. That involves some discrimination, because the price of laying pipe varies in different parts of the territory served. In some parts, rock excavation may be encountered; in other parts, water; in other parts, pipe laying may be cheap. It is more satisfying to the public and strikes people as fairer when the applicant is told: "We will make an estimate of the cost of this extension, and having made such an estimate we will submit it to you. Your charge will be based on the actual cost of the extension. If when the extension is laid the cost is less than estimated the charge will be reduced accordingly. If more, we will charge you no more than the estimate." Under such circumstances the thing to do is to make the estimate cover the cost, and that may easily be done so there is no serious loss. On the other hand, the applicant is gratified if the water works comes back with a notification that there is a reduction in the estimate of the cost of the extension.

Now, having determined the cost of the extension, it is easy to estimate the fair return, taxes, and depreciation on it, as well as the maintenance cost.

The second step is to ascertain the fair proportion of the fixed service or static costs of the entire plant chargeable to the extension. To do this it is necessary first to ascertain the proportion of the total fixed charges

and operating expenses of the entire plant which may be properly allocated to fixed service or static costs.

Having done this, the total fixed service or static cost of the entire plant may be reduced to a convenient unit basis, as, for example, so much per foot of main. A charge of so much per foot of main for the extension's share of the gross fixed service or static cost does not take into consideration the size of the main to be extended and, therefore, it is more equitable to reduce these costs to the inch-foot basis. By inch-feet in an extension is meant its length multiplied by its diameter. Thus a 6-in. extension, 100 ft. long, will have 600 in.-ft.

By dividing the total fixed service or static costs of the entire plant by the number of inch-feet in the distribution system, ascertained by multiplying the length of each size of main in the distribution system in feet by its diameter in inches, the cost per inch-foot of the fixed service or static charge may be determined. Multiplying this cost per inch-foot by the number of inch-feet in the proposed extension fixes its proportion of the total fixed service or static cost. The rule, therefore, for determining the proper charge for an extension may be stated as follows:

1. Ascertain the cost of the extension.
2. Determine the annual cost of the extension, including:
   a. Fair return on the cost of the extension.
   b. Taxes on the extension.
   c. Depreciation on the extension.
   d. Maintenance on the extension.
3. Take from 20 per cent. to 40 per cent. of the gross cost of service (gross cost of service equals fair return, taxes, depreciation, reserve, and operating expenses) as the proper portion chargeable to fixed service or static costs.
4. Divide the total fixed service or static cost by the number of inch-feet in the distribution system to determine the proper fixed service or static charge per inch-foot of main.
5. Multiply the number of inch-feet in the proposed extension by the fixed service or static charge per inch-foot as determined to ascertain the fair proportion of fixed service or static costs which should be allocated to the extension.
6. Add the fixed service or static charge for the extension to the costs chargeable to the extension proper to obtain the total annual costs chargeable to the extension.

Now comes the question as to how the consumer is going to pay the cost of an extension, and in my judgment it is better to have a flexible rule by which the individual preference of the applicant or guarantor for the extension may be satisfied. Some prefer to pay a sum sufficient to cover the cost of the extension at the time the extension is made. Others prefer to pay an annual sum equal to the estimated annual charge for the

extension; or, in other words, to pay for the extension in installments. Some water works allow the applicant to pay for the entire cost of the extension, but such a payment does not cover the cost of an extension, as it saves the water works nothing but the interest on the money which it would have to secure to pay for the extension. If the guarantor is allowed to pay for the cost of the extension it should be understood in the extension agreement that the difference between the revenue actually received from the extension and the fair annual cost of the extension as determined shall be deducted year by year from his payment until such time as the revenue from the extension is sufficient to pay the annual charges against the extension, and that there will be returned to him only the net balance due him after deducting the total annual cost from his deposit.

A better way to handle a flat payment is to estimate what the total annual charges on the extension will be for a covering period, say ten years, and to require the guarantor to deposit this sum with his extension agreement. In such a case the extension agreement will provide that only the actual differences between revenues from the extension and charges to the extension will be deducted, and any balance remaining at the termination of the extension contract will be refunded to the guarantor.

Another way, as I have already suggested, is to have the guarantor guarantee the annual revenue required to pay the annual charges for the extension, and if this is done it is necessary for the guarantor to furnish security so that the water works may be assured that the annual charges for the extension will be paid. This may be done by requiring the guarantor to file a surety bond, or bond endorsed by reputable citizens of the community, as sureties who are satisfactory to the water works.

As soon as an extension goes into service it usually pays some revenue. Statistics which I have collected on different water systems indicate that a large percentage, possibly 80 per cent. or 90 per cent. of all extensions, pay the extension charges within ten years. It is undesirable to have long extension agreements, as it increases the number of such agreements outstanding unnecessarily, making unnecessary bookkeeping and unnecessary trouble. Moreover, there is some question as to whether or not a special extension does not within a certain reasonable time, whether it pays or not, become a part of the distribution system, so it is usually a good plan to agree to return the balance due from a cash deposit, or to release the bond under the annual payment plan, at the end of ten years. The water works will suffer very little loss on this basis, and it removes many causes of complaint against extension charges. The extension contract should provide in any event that it will be automatically cancelled whenever the revenue received from the extension equals or exceeds the amount required to pay the annual charges on it. In the case of a cash deposit, the balance due is returned at the period of cancellation whenever it occurs; and in the case of a guarantee the bond is canceled in the same way. In that way the extension takes its place as a permanent part of

the distribution system as soon as it commences to earn sufficient to carry it and it ceases to be a special extension.

There is one more point that I should touch upon, and that is: What revenues should be deducted from the gross charges above outlined? The methods of charging for service are so different in different water works at this time that it is almost impossible to make a general rule on this question. I can do no more than outline the principle involved.

In the case of many extensions a water works will be immediately possessed of the income from the hydrants set on the line. If the entire fire service revenue of a water works is obtained from hydrant rentals it would be unfair to deduct the entire revenue from hydrants from the extension charge, as a portion of this charge goes to repay the water works for the fair return, interest, depreciation and maintenance of the hydrant and its connections.

Where fire service charges are paid on the inch-foot basis, the inch-foot revenue on the extension is a proper deduction. Where the hydrant charge is a nominal one and only sufficient to cover the fair return, depreciation, taxes, and maintenance of the hydrant, the hydrant charge should not be deducted. The revenue which a water works receives from consumers along a line cannot all be treated as a proper deduction from the extension charges. A sufficient amount should be reserved from the water-service revenue along the extension to pay for a fair return, depreciation, taxes, and maintenance of the meters and service connections, as well as the inspection, repairs, and renewals of meters and the reading and billing of meters. This will usually amount to from 40 per cent. to 60 per cent. of the minimum charge. The rule in relation to water-service revenue from consumers along the line should be, therefore, to deduct 40 per cent. to 60 per cent. of the minimum charge from the water revenue received from each consumer and apply the remainder as a credit to the extension charges.

I have made this outline as brief as possible, but I think I have laid down principles which I am convinced are right after working out extension agreements in a number of places. Extension agreements must be modified in individual cases to suit special conditions, but if they are properly prepared and if pains are taken to explain to the public just what they mean, there is little or no dissatisfaction and the water works receives a material revenue from special extensions. In one company that I know of the revenue from extension contracts amounts to between \$25 000 and \$30 000 a year, and that indicates the amount of discrimination of which a water company may be guilty in making extensions without a specific charge. Were there no extension contracts in the case mentioned, the other consumers on lines already existing would have to carry that \$20 000 or \$30 000 a year.

There is one thing more I should like to touch upon. Sometimes it is difficult for a water works to decide whether an extension is a special

extension or an extension which the water works is obliged to make for the purpose of giving adequate service in territory which is already covered. The tendency, of course, is to secure all of the revenue possible from extensions, but it sometimes happens that the distribution grid is not thoroughly connected up and extensions should be made to give proper circulation. An extension made under these conditions does nothing more or less than perfect the grid to give good service, and, when an application comes in for an extension which is necessary to complete proper circulation, no extension charge should be made.

I would urge that in all cases the consumer be given the benefit of the doubt, because I believe in the long run it pays always to give the consumer the benefit of the doubt. Such cases are not frequent. Usually, special extensions are capable of being easily fixed as such, because as a rule such extensions lead away from the existing distribution system for the purpose of supplying an individual consumer who builds on the outskirts of the town. When cases do arise, however, where a consumer builds within the distribution grid on a street where a main has not been laid, it is well to give the consumer the benefit of the doubt.

Discussion.

Mr. Frederic I. Winslow.* I should like to state the policy in Boston for the last thirty or forty years in regard to pipe extensions, which for twenty-five years were in my charge.

The system in Boston has been, during that time, to base the charge simply on the length of pipe multiplied by $1.30, which was for many years the cost of laying 6-inch pipe in ordinary soil. No matter what the size actually laid was, we charged $1.30 a linear foot down to the front of the house as the cost basis. We then took the income from the house, estimated on the schedule rate, as there were few meters, and if that amounted to 6 per cent. of the cost of laying the pipe, the pipe would be laid. This plan worked very well.

Of course, when a street was first opened up, a person building a long way from the main pipe line — because there the land cost less and it cost less to build, and these were the first on the street to ask for water,— if the income was not at least 6 per cent., was called upon to make up the difference multiplied by five. If the pipe cost $500 to lay, on a basis of $1.30 a foot, requiring $30 a year, and this house would yield but $15, he was taxed $75 for a five-year term. This amount was deposited in a bank, as a separate account. If any one built on that line within five years, the first comer got back all that was paid in to the city on that line, up to $75, so that he might get back at the end of the five years a part of his deposit, or perhaps the whole of it — oftentimes he did get back the whole of it.

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* Division Engineer, Metropolitan Water Works.

Of course the laying of the main pipe meant more buildings; it increased the demand for the land, because land is more valuable, and can be used to better advantage, as we all know, if there are water pipes in the street.

In regard to hydrants, for a long time Boston had a charge of $18 for a hydrant, paid by the city. That was added oftentimes to offset a low revenue, which made very much less to be paid by the water-taker. Later, it was reduced to $2 per hydrant. I think that now they charge nothing for hydrants — at least, they did not the last I knew.

This system has worked well in Boston, and has worked little hardship, as viewed from the standpoint of a water-works man.

Mr. Francis T. Kemble.* Mr. President, I think that Mr. Hill's paper contains food for a lot of thought. My experience has been that the majority of pipe extensions prove of good service afterwards.

I know of four different methods in regard to payment. Of these I think the method just spoken of, the inch-foot basis, is a particularly fair one. I know that with some companies other than my own, the laying of pipe on a system of a guaranty of certain revenue has proved a source of great annoyance, — a discussion every time a bill was rendered. Where a developer pays the entire cost, I have known cases where it has been difficult to make them understand that they were fairly dealt with, particularly where a single company was developing more than one tract and found the cost of piping some streets amounted to considerably more than others. As a general rule, if the developer is at all successful with his property, manages to advantage, the rebates that he gets because of house connections or hydrants bring him back the money he has had to lay out, without considering that the value of his property has been raised because of having been piped for water.

There is one other method which I do not think has been mentioned that has been adopted by some municipal companies, that I believe has worked to advantage, and that is charging the abutting property so much per front foot on property on streets in which pipe is laid.

Mr. Caleb M. Saville.† In the matter of laying these assessments, it is becoming a considerable question in some of the towns and cities — not perhaps so much the matter of what the assessment shall be, but how that assessment shall be laid.

In Hartford, and I think also in most of the New England States, but not so much in other sections of the country, we have what is known as a "guaranty." That is a guaranty to pay a certain per cent. of the cost of the extension. There are some things about this method that work hardship, and I will try to outline some of them.

The general scheme is that somebody who owns a house on a new street, perhaps over a thousand feet down, wants a pipe extension. Per-

* Secretary New Rochelle, N. Y., Water Company.

† Engineer of Water Board, Hartford, Conn.

haps there are two or three lots which have been opened up on that street, all on one side, let us say. We say to them, "Yes, we will lay that pipe provided you will guarantee 10 per cent. of the cost of laying the extension." Now this agreement is a joint and several guaranty; it is a personal guaranty, and has nothing to do with the land. There is no lien on the land, and if the guarantor moves away or becomes bankrupt there is no way of enforcing collection.

In one city that I know of in Connecticut — Bristol — the cost of pipe extension, through an amendment to their charter, has become a lien on the property. Whether or not that is a wholly good method I prefer to let some one say who has given study to the matter of special assessments.

Now, the men that undertake to put this pipe in, 1 000 ft. long — five of them, we will say — have made themselves personally responsible for the cost of the work. Perhaps they have 60-ft. lots all on one side of the street. That leaves vacant land on one side of the street, and perhaps also between the houses there are vacant lots. Perhaps on the vacant side the land is owned by one person, — a farmer, — and he does not care to develop it. Now he pays nothing because his name is not on the guaranty. The people who guarantee alone are responsible.

The pipe goes in and the people who are responsible for it get their water. Then one of the vacant lot men who would not sign the guaranty applies for a connection, and gets it, with all the benefit and none of the responsibility.

Besides this, there is the increase in value of all abutting land. Immediately a pipe is put into a street it increases the valuation, and the real estate people are very keen in advertising that there is city water in the street.

Now, my question is, — and I wish very much that it might be discussed here to-day very briefly: What is the best way of handling such a proposition, — of handling these extensions? I should be very glad if Mr. Hill would say what he has found in his experience.

Mr. Hill. I think Mr. Saville brings up a most interesting point, and one of the most difficult points in connection with extension charges. I purposely omitted reference to the property assessment method of paying for extensions, because I tried to obviate as far as possible differentiation between a private water company and a municipal plant, and, of course, the property assessment method of securing extension costs is not possible with a private water company. However, I do believe that the method of assessing abutting property for extension charges in municipally owned plants has much in its favor and is worthy of serious consideration.

Touching upon Mr. Saville's point as to the unfairness between the guarantor and others who come in on a new extension, it has seemed to me that the discrimination is more theoretical than actual. In the first place, the guarantor, as soon as others come in on the line, receives the

benefit of any deduction in the revenue guaranteed as the revenue from additional water-takers increases, so that not only is his actual cost reduced but he is responsible for his guaranty for a much shorter space of time.

It must be remembered that it is the one who demands an extension whose needs are primarily satisfied, and that when the extension is made the water purveyor has no knowledge of what the revenue is going to be. In order, therefore, not to place an undue burden upon existing consumers by accepting undue risks, some one must be held responsible for the revenue in order not to discriminate against existing takers. The guarantor receives the benefit that he wants to get at the time, and all revenues subsequently obtained from service on that line go as a credit to him, and are deducted from the extension guaranties of the guarantor, so that when you figure it out, discrimination is really not as great as it seems.

Now, if it seems unfair that some individual or group of individuals wants to take advantage of some other individual or group of individuals, and will not become a party or parties to an extension contract, and places the burden upon other individuals or group of individuals of guaranteeing the revenue from an extension, that condition cannot be laid at the door of the water purveyor. That is human nature. You will always find people of the type who will refrain from signing an extension guaranty from which they will benefit, and this cannot be helped. If the individual or group of individuals who will sign want water, then it will be obviously unfair for the water purveyor to refuse to make an extension because of those who will benefit and will not participate in the guaranty.

Now, when the extension contract is once made between a water purveyor and the guarantor, a legal point is involved. There is no way by which other parties desiring water from a given extension can be made parties to the contract except upon abrogation of the existing extension guaranty contract and the making of a new contract. Now, it is obvious that such a course on the part of the water purveyor would be inadvisable, because the chances are that the parties who would not attach their signatures to the original contract will demur in signing any later contract; so the best the water purveyor can do is to place the responsibility for the guaranty upon those who are willing to accept it in order not to discriminate against existing water-takers and to credit these guarantors with all of the revenue which should properly be credited to the extension which they have guaranteed. Under these circumstances, every house that goes on to a new extension reduces proportionately the guarantors' liability and decreases by so much the period during which the guarantors will be responsible. This is one of the minor points which I can see no way of clearing up in the case of a private water company. If, in the case of a municipal plant, property is assessed for the cost of the extension, then, of course, all property can be assessed without discrimination; and for this reason alone it might be a fairer way than any other for assessing pipe extension charges under municipal operation, to say nothing of the

property benefit which accrues to all property owners by reason of having water adjacent to the property.

Mr. J. M. Diven.* Mr. President, I think I have used one method of getting around Mr. Hill's objection, and that is to give the guarantor control of the main as long as the guaranty lasts. If anybody else wants to come in he must deal with the guarantor and make his bargain with him before he will be allowed to attach to the main. In other words, the guarantor can compel others to assume their fair proportion of the guaranty.

Mr. Saville. That would seem to bring the question more into giving the private man some control of the city property — I am talking from the municipal side of it. I wish we might hear from Mr. Gear as to how he does it in Holyoke, because it seems to me that they have worked out a system up there that is good, and if there are any holes in it I should certainly like to know what they are.

Mr. Hugh McLean.† I have always considered that water should be sold at the cost of delivery from the mains to the residences as far as possible, and that all the other benefits, such as fire protection and increased extensions, should be paid for as laid down, thereby putting the cost at the time of the installation on the individual who acquires the benefit, whether the price be high or low at that particular time.

About five years ago our revenues were not increasing fast enough to meet the cost of the desired extensions. For example, a farm, a tract of land out in the suburbs, was bought by some land speculators, and laid out. Now, in former times on petition we would extend the water pipe up all streets cut and laid out, and make no charge for it. But that was in the days when pipe was costing $15, $20, or $25 a ton. When, however, the cost got up to $100 a ton, and labor cost two or three times what it formerly did, it was a different proposition.

So to increase our revenue primarily, and to get some benefit from those extensions other than the revenue from the sale of water, we thought it out and adopted a charge of a dollar a front foot on all new extensions, and have had very good luck with it so far. Occasionally we are confronted with a statement that it is not legal, but so far we have gotten away with it.

If a pipe is laid 300 ft. on a street, and if the man at the end of the street wants the water first, we do not charge the others the dollar a front foot until they take the water. We are wondering whether or not we should amend our rule and make the charge on the other owners at once. Sometimes they say, "We are satisfied with our well water; we don't want the city water now, and don't know whether we will ever want it." But if we can be protected by a lien on that property, so that if it is sold at any time the buyer will know that there is a lien on it, then we will be all right.

* Secretary American Water Works Association.

† Water Commissioner, Holyoke, Mass.

Awhile ago one of our leading educators bought a place, and found one of these liens was on it, where they hadn't paid the dollar a front foot. We would not put the water in until he paid. He threatened to contest our rights and took legal advice; but we have gotten away with it so far.

It seems to me the simplest way to do is to finish your job while you are at it.

If the pipe line is laid, the real estate man sells his lots, and gets the benefit, and the builder is getting a good price for his work, all the other utilities are being paid for, and I think the people benefited should pay a proper amount for the extension of pipe lines. We have so far maintained the same low price for our water, but have got to provide additional revenue, and that was one of the steps taken. A dollar a front foot does not cover all the costs, but we thought that it was reasonable in view of the fact that some of the present users had their extensions put in for nothing when the prices were low.

Mr. Patrick Gear.* In making this front foot charge, we found that there were two streets side by side, and pipe was laid in one that was opened up nine or ten years ago on which a couple of houses were built.

The lots were sold for $50 more on the street where the charge was made than they did on the older street, so that we put a service charge on all vacant lots on the older street. We do not care how long the pipe has been in,— it may have been in forty years,— we now apply a service charge and are getting some revenue from that. We also have $10 for a 1-in. tap, besides charge for installing the service, $15 for $1\frac{1}{4}$ in., $20 for $1\frac{1}{2}$ in., $25 for a 2-in., $35 for a 4-in., and $50 for a 6- or 8-in.

In Holyoke we furnish water so cheaply that if the streets were all built up to-day, our charges would not cover half the cost. The places where we get the revenue is where they build up in the air. If all of our streets were built up with one-family houses, we could not pay our expenses in Holyoke.

There are some of those fellows who try to beat us a little now and then, in a very jolly way. Take the case of a man who is on the corner of a street, and there has been a pipe on one of those streets for twenty years. The other is a new street which has just been opened up. He says, "I will tap on the pipe on the old street and I won't have to pay anything." We say, "No; you must connect on the side street; the other is a main pipe and you can't tap it; but we will charge you by the front foot." Now, he has a 50-ft. frontage on the main street and 150 ft. deep on the side street, but in that case we only charge him the $50.

Mr. David A. Heffernan.† Mr. President, the plan used in Milton works out very well. In cases where the extension of mains in unaccepted streets is applied for, the cost of the work is estimated and a deposit of 25 per cent. of the cost required. This insures an income of 5 per cent.

* Superintendent Water Works, Holyoke, Mass.

† Superintendent Water Works, Milton, Mass.

annually on the outlay for a period of 5 years. This deposit is placed in a savings bank. If the applicant desires he may pay this 5 per cent. each year and leave the bank deposit intact. If not, the department withdraws from the bank a similar amount. At the end of 5 years the applicant receives the balance of the deposit with the interest it may have earned.

Mr. Reeves J. Newsom.* I would like to ask Mr. Heffernan, in the working out of his plan, if the original development is made by some man who is building houses to sell, and if he makes a deposit to cover an extension for three lots, say, and then shortly afterwards sells two or more of the houses, what becomes of his deposit in the bank?

Mr. Heffernan. We hold the man who makes the application, and do business with only one man. He has to make the deposit, and that is held up until the end of the five years.

Mr. George F. Merrill.† Mr. President, I believe that Mr. Gear has the fairest way of distributing the cost. I do not know what authorization they have for it, but, at any rate, it seems to me there is a chance right there for a little legislation that would make it a whole lot more equitable to the people that own lots on streets that are built up. I think the way Mr. Gear has worked it out might be taken as a basis for legislation.

Mr. A. R. Hathaway.‡ This matter has been quite a problem in Springfield for some time, as some of you may know. Our system is somewhat similar to the others; we have a guaranty which, when signed, becomes a personal agreement, as Mr. Hill says, and is not a lien on property.

We sometimes receive notices from people who signed such an agreement, that they have sold their property abutting on the extension and that we should look to the new owners for any charges under their guarantees.

We immediately tell them that *they* are the persons who are responsible, as they are the guarantors, and that they should arrange with the new owners for taking care of such charges, if they so desire, when we send the bills to the original signers. We have had very little trouble in that direction.

I was glad to hear Mr. Hill bring out one point in his paper, and that was his recommendation of a time-limit for such agreements. Most of our difficulty in collecting charges under our guaranties has been due to the one undesirable feature of a possible " forever " period of responsibility.

Our guaranty reads that the signers shall pay upon demand the annual amounts set against their respective signatures until such time as the revenue derived from that particular extension,— from themselves as water-takers, or from other water-takers on that line,— shall equal or exceed the aggregate amount of the guaranty. Naturally most of our guaranties

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* Water Commissioner, Lynn, Mass.

† Superintendent Water Works, Greenfield, Mass.

‡ Water Registrar, Springfield, Mass.

are soon canceled by the water revenue received, while some run for many years, and a few bid fair to "go on forever." At various times I have suggested to our water commissioners the adoption of a time-limit,— preferably a ten-year period,— which is the limit recommended by Mr. Hill in his paper, as I understand it.

I have in mind one place (I cannot recall the name now) where they have a five-year limit. The adoption of a limited period, I think, would do away with the trouble we are now having at times.

Only last week a young woman called at our office to ask how long her guaranty was likely to run, and she was told it might be "forever, unless some additional water-takers become connected to that main, or the present takers let the water run through their meters, so that our revenue for that line during any particular year will equal the guaranteed amount."

It seems that she owns a lot on a street where a small extension was wanted by two other parties who had put up houses, and who signed a guaranty for certain amounts, and who persuaded her to sign for five dollars a year, also.

She stated that she does not expect to build on her lot, but may some time sell it. For six years, I think, she has been charged the $5.00, and it was when receiving the last bill that she made her inquiry.

While the "forever" period was naturally not pleasing to her, she said she supposed her lot was really worth more for having a water pipe run by it, and that she supposed the charge must be all right. I told her that the only way I could see to help her out was to sell the lot to somebody who would build on it, or else build on it herself, and she finally appeared to accept the situation.

But, as I stated before, I am of the opinion that a proper time-limit of five or ten years would be the means of helping us out in the matter and would in my judgment be the proper thing.

I do not know how you can make the guaranty any stronger than a personal agreement in Massachusetts, so long as the state laws do not make such charges a lien on property.

There is one thought that occurs to me, and that is that in making such extensions it should not always be considered necessary to assess the entire cost, or the full interest equivalent on the cost, on the parties to be at once benefited. I have read a number of opinions handed down by Public Utility Commissions in different states (pertaining to privately owned utilities, such as water, electric, gas, etc.), where they questioned the right of such utilities to *refuse* proper extensions of service in cases where the entire interest charges, or costs, were not previously guaranteed or met by the petitioners. In other words, such utilities were held to a certain degree of obligation to serve the people who may build beyond the present limits of their mains or lines, notwithstanding the fact that a full return might not be at once realized from the extension investment. So that, if this be true in a measure concerning private utilities, how much

more should it apply to a municipally owned utility! This point, it seems to me, should be borne in mind when we are thinking of and discussing this subject.

Mr. Saville. Mr. Hathaway speaks about the five-year period. I think there is a law on the statute books of the state of Minnesota saying that it shall be paid within five years.

I should like to say that one of the jokers in this scheme Mr. Hathaway has spoken of — that is, this guaranty forever, which we have in force, too, and have run up against it in one place — is that it says that until the revenues are equal to the water rates. That means that if any man is keen enough, and has it in mind, he will let his water run for one year until he gets up to that guaranty, and then having got to the place where the requirements of the guaranty are fulfilled, he can shut the water off and he is through with the guaranty.

Mr. George A. King.* Mr. President, there is one point which Mr. Hathaway spoke about, viz., the transfer of the guaranty to the new owner. We have a city solicitor who ruled that the water commissioners had a right to charge a special assessment because of special privileges, and that if we made this extension we could require a new owner of the property to pay that, provided he took the water. That is, we could refuse to let him have the water except he paid the guaranty which his predecessor had made. Our guaranties are for five years.

Mr. William A. MacKenzie.† Mr. President, Wallingford has the same arrangement as in Springfield, and it has worked out successfully. It seems to me in a municipal plant that the vacant lots are enhanced in value, and the taxes derived from that particular development are greatly increased, and indirectly the municipality receives the benefit which perhaps was partially brought about by the department in laying water mains through the new section. I think the ten-year clause would be a very just proposition to bring into this consideration of the percentage of the cost, and then have the limit ten years, and the money derived from taxes would indirectly help to carry the cost of the extension. The private plant might be somewhat different.

Mr. Hill. I want to make one or two remarks in closing this discussion.

I have no particular preference for any method of assessing extension costs. My intention this afternoon was to bring to the attention of the Association, first, the absolute necessity and fairness of making an extension charge; and, second, that a fair extension charge is a computable thing however it is assessed.

I think objection to the extension charge is largely because such charges have been made in a hit-or-miss fashion, without regard to the method by which the charge should be determined. Now, it is perfectly

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* Superintendent Water Works, Taunton, Mass.

† Superintendent Water Works and City Engineer, Wallingford, Conn.

possible, whether an extension charge is to be levied on the inch-foot basis at so much per foot of pipe, as a fixed sum, or assessed at so much per front foot of abutting property, or in any other way, to ascertain what the fair charge should be for an extension under each condition, and with this fact borne in mind it will be possible to adopt the basis of charging which is best suited to the local requirements, to the municipal or private plant, and to meet the conditions and laws in the various cities governing the collection of such charges, for these laws also differ.

That is the one point that I wanted to bring out in closing this discussion, — that proper extension charges may be computed, and in making such charges the basis for the charge should be accurately ascertained.

Mr. McLean. In Holyoke the engineer estimated the cost of laying the pipe on this new farm tract at about $2 a foot, so that rather than charge them the full expense we went halves with them, figuring that it would be giving them about what the former water-takers used to get for nothing.

RELATIONS BETWEEN PLUMBERS AND WATER-WORKS SUPERINTENDENTS.

BY G. WILBUR THOMPSON.*

[*February 9, 1921.*]

Mr. President and Gentlemen, — Your business is largely outside of my zone of activity, and the few things that I may suggest are those that have appeared to me through my many years engaged in the plumbing business, but what I am to dwell upon largely will be the activities of the plumbing industry at the present time as compared with those of two generations ago, and down through to the present time, and in so doing I may be able to point out, in a way, a relative contrast in your work through this time as well. We are very closely allied, as no plumbing would be of any use except for the supply of water; and, on the other hand, very little water would be needed, in comparison, if the use of plumbing had never been generally adopted.

The plumber has to deal with the two greatest elements of creation, — fire and water, — and I will ask your indulgence to diverge for a moment and enter into a personality, that I may surround myself with the proper scenery or background by approaching the main subject in a reminiscent way.

I was born up in the woods of New Hampshire, and when very young, long before I even knew the definition of the word "plumber," and before I had learned to respect the great value of fire and water if properly controlled, I knew the absolute terror and destruction of both, as I had witnessed them when left to their own fury and uncontrolled. I can even recall at this moment the terrible nightmare of the burning of a large set of farm buildings, including all of the live stock, and two elderly people as well; and I suffered many times during my childhood the fear and dread of the fury of water during the heavy fall rains and spring freshets, when the little brook that flowed a few yards in the rear of my home would rise many, many fold above its normal capacity, and sweep onward and take everything before it.

There were several dams on this particular stream, where were located sawmills, gristmills, tanneries, etc., as were so common in the old days, and I can recall at this time in a heavy fall of rain when the upper and largest dam gave way, and on came the rushing water in all its fury and power, sweeping before it all of the other dams and bridges. What particularly impressed and affected me most was that it swept all of the soil from the

* President of the Massachusetts Association of Master Plumbers.

land connected with my little home, taking an orchard of about fifty grafted fruit trees, flooded the house, and came near taking it along as well, — practically ruining our home, which meant so much to us at that time. These, gentlemen, were my first impressions of fire and water, and they have dwelt with me down to the present time.

I left home when about eighteen years old and bound myself out for three and a half years to learn the business, as was the custom then, and served my full time. I then went into the employ of the Boston, Concord & Montreal Railroad, which was afterwards absorbed by the Boston & Maine, as a journeyman, and remained in their employ for thirteen years, and during the last five years had charge of the heating, plumbing and waterworks of the White Mountain Division, extending from Nashua and Portsmouth, N. H., to Fabyans, and lateral lines, and during that time I had a very broad experience in water supply, ranging from and including the old-style suction pump, windmills, gravity, steam pumps and hydraulic rams. The most difficult thing of all was guarding against the cold we had in the mountains. Twenty-five years ago I severed my connection with the railroad and engaged in the plumbing and heating business at Newton Centre, where I am still located.

Two generations, or fifty years ago, there was very little plumbing in the large cities and none in the country, as many of you gentlemen know, and even down to thirty years ago there had not been very great progress made in the plumbing industry, for at that time the fixtures were all cased in, and the water-closets largely were either of the Zane, the Detroit, or Pan styles, which, *especially* the first two mentioned, were of the vilest character, and not much improvement over the old dry vault. From that time on, the industry began to take on a new life, when enamel ware first began to appear and the open plumbing began to be introduced. From that time down to the present you all realize the great transformation that has taken place, and especially so during the last decade.

When I was elected last April to the presidency of the State Association, I, like all others, wished to do something different from my predecessors, and the first thing that appeared on the horizon was to change the style of the old stereotyped stationery that had been used for so long, and I conceived the idea that I might, if possible, procure a cut of a complete bathroom as installed in 1893, the year that our association was organized in Massachusetts, and place it at the top of the letter sheet with the year "1893," and at the opposite corner put a picture of an up-to-date bathroom of the present time. This I did. I had much difficulty in procuring the old cut, but finally I was able to get it and to do this with much satisfaction. My object in doing it was to remind every member of the craft, both young and old, who might see these pictures in contrast, of the very great improvement that has been made in our industry during the last generation, — and it has been especially marked during the last decade.

When I first engaged in the business for myself it was quite rare to have more than one complete bathroom in the ordinary house, and all of the plumbing in the house was put in at an expense of a few hundred dollars, whereas to-day the real estate brokers tell us that people generally will hardly care to look at a house unless it has two or more complete bathrooms, and all other plumbing accessories as well.

In 1916, I completed the installation of plumbing in a residence that cost in round numbers twenty thousand dollars. To-day it would be nearly double that amount. I simply speak of this to show to what extent the industry has grown and to what extent it is demanded at the present time.

Without modern plumbing the high commercial buildings would be impossible, the gymnasiums and hospitals much less efficient, and at the same time it has proven itself not only to be a great comfort, value and satisfaction in every-day life, but it has become a necessity to such an extent that the towns, cities, states and even our National Government are enacting laws to compel all of the great industries to install proper plumbing in their factories and places of business where help is employed, and this plumbing is required to meet every demand to safeguard the health of the operative while at work, as well as at his or her own home.

Another great advance that has come about within a comparatively short time is the public comfort stations. All of you gentlemen will agree with me when I say that no other name could be better applied to these stations than "comfort," for they are that to the fullest meaning of the word, and when we think of them as comfort stations we don't want to lose sight of the fact that there is a moral value in it, in the way of protecting the privacy of the sexes to a large extent, as if in their own homes; and again, it tends to protect the comfort and health of the person by being able to respond to the call of nature instead of postponing it, which, as we all know, is a very dangerous thing to do.

Another, and what I deem as a very encouraging outlook of the business from a physical standpoint, is that it is no longer a city proposition and necessity, but it is being introduced and enjoyed in the country homes as well. This phase of the business is going to have a very far-reaching and beneficial influence upon the young people in inducing them to remain on the farm and to adopt and carry on agricultural pursuits as their life's vocation, as has been done by their parents and perhaps grandparents for many generations before them. And why? Because when the young go away to the city, or to school, they enjoy all of the up-to-date life that is afforded them at these places, and after once enjoying this life, it is very hard for them to return to the farm and be deprived of it, and the longer they remain away the harder it is for them to return; and that is the principal reason why so many in the past have abandoned the farm and gone to the city to dwell.

But this condition is being changed, and will continue to be changed, as time goes on, by reason of the fact that the time has arrived when people

living in the country may enjoy practically all of the privileges of city life. To-day the farmer is in close touch with the outside world by means of rural delivery, the telephone; and, yes, I might add, the auto, and now through the addition of electric lights or gas and modern plumbing, as you will see in many country homes, — but perhaps more so in the West or Middle West.

What inducements has the city over the country to offer the young man or woman from the farm? To-day the farmer's son and daughter, by means provided through the many splendid state agricultural colleges, and the up-to-date farming implements, become so educated and efficient that they may return to the farm and produce more and better products on ten acres of land, and with very much less energy, than their parents did before them on fifty acres. It is a well-known fact that the strength, health, and prosperity of a country depends to a large extent upon the success of its agriculture, and every inducement and encouragement should be given in that direction by the government and the people as a whole, and the above means when fully carried out will no doubt bring about the very best results for both the people and the country at large.

The plumber in the past has been treated as a huge joke. He has been cartooned, maligned, and more abused by means of cheap, stale, and uncalled-for jokes circulated through the newspapers and magazines, than all other artisans and professions combined. In the old days it might have been warranted to some extent, as the old-time plumber was a mechanic and not a business man, but to-day the whole condition is changed. I personally resent any of the cheap epithets and inferences applied to the industry as of the past, and our state and national organizations have convinced some of the leading papers and magazines of this country that it was not for their best interests to continue, and some of them have already apologized within a year for some of their publications that our state associations took exceptions to.

I am a plumber, not by choice but by condition; but as long as conditions made me a plumber I have tried to be a good one, and now that I am a plumber, I will say that I am proud of it. And why? First, because I am a producer, — for I am deeply impressed with the fact that any individual or any industry that produces that which will contribute the greatest good to the greatest number of people is the greatest benefactor; and, without being egotistical, I cannot see where any other industry adds more to the comfort and satisfaction of life to-day than the plumbing and heating industry. It is the very vitals of the home, the school, the church, and the factory, and modern life could not continue and improve morally and physically without it.

And then again I am proud to be engaged in the business because it requires long experience and good judgment to equip the enormous buildings of this time with heating and plumbing; and, again, because it is interesting, as no two buildings or propositions are alike; and, again, be-

cause we are the only artisans who are required to pass a rigid examination by a board appointed by the state before we are allowed to go forth as journeymen. Why? Because it is, in a way, a profession as well as a trade, for the public depends to a large extent upon our industry for the protection of its health. We protect, as far as possible, not only the physical but spiritual as well, for it has been said that cleanliness is akin to godliness, and where we fail it only remains for the doctors, ministers, and undertakers to do the rest.

And now, last but not least, I am proud I am a plumber from the fact that no other business has made such an advance as our industry has during the last decade, and the possibilities are still greater for the future than in the past by reason of the great educational campaign that is being carried on through the efforts of our state and national associations, the National Trade Extension Bureau, and our splendid trade journals.

The Trade Bureau is made up and maintained by the manufacturers of plumbing and heating supplies and the Master Plumbers of the United States. Well-qualified field men are furnished by this organization and distributed all over the country, each to cover a certain section, who are at the disposal of the local associations for the purpose of teaching them how to arrive at costs or overhead in business; how to show goods; and, in fact, everything that may improve our business from every angle. This is without doubt the greatest educational campaign ever inaugurated by any business, and through its efforts we feel very hopeful that our industry will not be longer treated as a necessary evil, as in the past, but looked upon as one of the greatest and most respected of all industries, and through these efforts we are encouraged to entertain the hope that we may soon be recognized as justly entitled to occupy one, if not the highest altitude in the constriction of business, a position which is due us and which we rightfully should have attained long ago.

Now, gentlemen, in setting forth the business as I have, I have not lost sight of the fact that you are entitled to your share of the glory; for, in a way, plumbing is wholly dependent upon the supply of water, and the possibilities of furnishing water for the increased demands has been just as much of a problem, and perhaps even greater, to meet all of the changed conditions, and the able hydraulic and mechanical engineers who have been able to furnish all of the machinery and lay-out, and perfect the great water supplies, are worthy of the greatest praise and appreciation.

One of the greatest problems that we have to meet is the pipe question, and that can only be met by the analysis of the water in each locality, and the chemical action of the water on the different kinds of pipe. That is a local problem. We have been greatly disappointed, in Newton and Brookline, in the use of brass pipe. Owing to the large amount of carbonic gas contained in the water, its action upon the pipes either crystallizes them to such an extent that they become as brittle as clay and break off at the thread, or they become thoroughly pitted the whole length of the

pipe. I have done work all over New England, and it has been very interesting to see the different results, in the various localities. On the whole, for every locality and every condition, I believe the lead pipe has given far the best satisfaction.

In the beginning, I mentioned that I had only one or two suggestions to make, which are: That the smallest supply to any building should not be less than one inch inside diameter, increasing in size according to the demands of the household. The distance from the main to the building should be considered, and especially so under a low pressure, where a larger pipe should be used, as it is a fact that friction has much to do in reducing the pressure and volume of water delivered as the length of pipe increases. In other words, much more water will be delivered when the delivery end is only 25 ft. away than when it is 1 000 ft. away.

I believe, gentlemen, that this suggestion is worthy of your consideration, at least to some extent; but the greatest mistake of all, as my experience has proven to me, is the meter. Almost invariably, where there is an inch or larger main, a meter will be placed that has only a half-inch inlet and outlet. Twice within a few months I have been called into two dwellings where there were several bathrooms, and on account of this very trouble when they drew water in one place it could not be had elsewhere in the house to any extent. On examination I found the piping in the house of ample capacity, but the trouble was wholly due to a half-inch meter.

Therefore I would recommend, for the good of the householder, that the meter should be equal to delivering as much water, — or, in other words, the inlet and outlet of the meter should be equal in size to main supply inside of building. From my point of view the meter, as it has been used, is the chief thing that should receive your attention in an endeavor for greater efficiency and satisfaction to all concerned.

There are other things I might mention, but I fully realize that this is a very dry subject, long-drawn-out and uninteresting, therefore I will close by reading this piece of doggerel rhyme that has recently come into my possession, and which seems quite appropriate for a symposium of this kind:

> "The drouth is on from shore to shore;
> The drouth is on forever more;
> The flames are seething from many throats,
> For the loss of liquids is getting their goats.
>
> "The drouth is on to this extent,
> It's driving some people to the devil hell bent, —
> With raisins and malt and inventions all new,
> They are making concoctions well known as 'home brew.'
>
> "Now ye men of distinction who keep on sale
> The best of all liquids, renowned Adam's Ale,
> Maintain a high test and you'll never relent,
> For selling the goods test 100 per cent."

Discussion.

Mr. David I. Heffernan.* I wonder if Mr. Thompson would inform us if he has used the Smith's temperature relief valve which is on the market. This is a pressure and temperature valve. There are several other good relief valves on the market, but this valve is a new one, and from what I understand, it is worth considering.

Mr. Thompson. I will say that I have had experience with about all kinds of relief valves. The whole thing has simmered down to one thing, — that the relief valve is of very little consequence on pressure work, and it has been proven beyond dispute that what makes the trouble is not the pressure, but it is the temperature of the water. You take a temperature of water of, say, 250 degrees, at a pressure of 80 to 85 lb., and if an explosion takes place you will find, according to capable engineers who are in a position to know, that when the boiler gives way the steam expands in the ratio of 1 700 to 1. That is 1 700 cu. in. to 1 cu. in. There is where the trouble lies.

In many tests that have been made, and explosions that have taken place right here in the city, and one in particular that we had pictures of, our association went so far as to get out books and pamphlets and send them to every member of our association in the state, describing it. It has been demonstrated that the very moment that anything gives way under hydraulics, that very instant, as you all know, the pressure is released, it doesn't spend itself to any very great extent; but if you have something that is compressed, like superheated steam, and then it gives way, that is when the damage comes.

You are alluding to Mr. Smith's valve. I do not believe that the pressure valves, as they are called, amount to a snap of the finger. With a valve so constructed that when the temperature of the water gets to a certain point it will melt and fuse the contents of that valve, relief is given before the damage is done.

There was a very bad explosion two years ago, in the South End, which did a tremendous amount of damage, but fortunately there were no people injured. It was proven that there was a relief valve that was supposed to open at 85 lb., — just a few pounds above the natural pressure, — and when the valve was taken off it was found that it would respond to an ounce to what it was formerly set at, and yet this pressure had gone very high by reason of the water being heated into steam. That is where, in every case, so far as I know, the damage occurs.

The only thing that I can say about Mr. Smith is that he has the nearest to it of anything I have seen, in my judgment. There are some things that he has got to correct before it will be used to any very great extent, and those things I think he has in mind at the present time.

* Superintendent Water Works, Milton, Mass.

Mr. Heffernan. I should like to ask Mr. Thompson if he would recommend putting a check-valve on a service, on the pressure side of a meter, if no provision was made for any relief or vacuum valve on the house side.

Mr. Thompson. I think that would be a very hazardous thing to do. The only relief is when the water can flow back through the meter, and some of the meters, I understand, are so constructed that they won't even allow that.

Mr. Morrison Merrill.* I should like to ask Mr. Thompson what he would recommend to save some boilers on high land from collapsing when we shut the water off suddenly.

Mr. Thompson. The only relief, of course, is a good, reliable vacuum valve.

Mr. Merrill. We can't depend on them.

Mr. Thompson. Of course there is nothing perfect in this world, but nine times out of ten I think a good vacuum valve will respond. That has been my experience. You are referring, of course, to a pressure job?

Mr. Merrill. Yes. A case of this kind occurred in my town last week. A main burst and I shut off the water without any notification, and a boiler collapsed. It was a heavy, copper-riveted boiler, and collapsed almost as flat as it could be if it was rolled out, but when the water was turned on the boiler took its natural shape.

Mr. F. H. Gunther.† That is something which should be embodied in the new plumbing regulations, — that there must be a relief valve on all pressure jobs, and is something which all water-works men have got to contend with. They will shut off a main and perhaps can't shut off all the services. Of course we shall have a collapsed boiler. Even pressure boilers will collapse under certain conditions.

Mr. Thompson. You get a Brown boiler — I am not advertising them — but I do not think you will have any trouble with collapsing under any condition.

Since the pressure boilers and the auxiliary gas heaters have come into common use the whole trouble has occurred. People will forget and leave their gas burners going under the gas heaters. After a few hours, of course, the water is heated to a tremendous temperature.

I was somewhat impressed by the result of these explosions, and I felt as though it was a very bad thing for the plumbers as a whole, because in several law suits the plumber has lost every verdict. In some cases he has been taxed with the expense of fighting the suit as well as the amount of the verdict, and it has cost him \$7 000 or \$8 000, which would ruin almost any plumber.

Now, I saw and considered that some time ago. I had an idea that when I installed a boiler, if I did everything in the world I could to put it

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* Superintendent Water Works, Wakefield, Mass.

† Superintendent Water Works, Dracut, Mass.

in properly, the man for whom I put it in must assume the loss if any explosion took place. So I made a draft of a release, and submitted it to my attorney, and also to another very able one, and to one of the judges of the Superior Court, and each one of them said that this release would hold water. It read like this:

Notice and Release.

In consideration of the warning given to me by . . . ., who is about to install a gas water heater or coil to a house heater in the premises at . . . ., and connect the same with a street pressure boiler, said warning being to the effect that grave danger attends the use and misuse of said heater or coil, I hereby agree that said . . . . shall be relieved of any and all liability for any accident or damage which may result *to any person or property* from the use of said gas water heater or coil.

. . . . (Seal)
Owner or Agent

Date . . . . 192 . .

Recommended and Approved by the Massa husetts State Association of Master Plumbers, Inc.

I had copies of this release printed, and sent them to every one of our master plumbers throughout the state, ten copies to each man, with a circular letter describing what it was for and all about it. A great many of them said no man would sign a release of that character. Their prediction has been disproved in almost every instance. I have put in quite a number of gas heaters and attached them to pressure boilers since that time, and not one person has refused to sign, and several have thanked me for calling their attention to the fact that they have a hazardous thing in their homes. They were not aware of it. That is the very point, — that they are apprised of it and they assume all responsibility if any damage occurs.

Now, that releases the plumber, but it does not release the householder from the possibility of these explosions. I will tell you here, gentlemen, that you want to be mighty careful to watch your gas heaters if you have them on a pressure job, for if you don't you may have to put a new roof on your house most any time.

Mr. Gunther. That would protect the plumbers, but where does the water-works man come in? I had an experience once, and got out of it simply because I laid it on to the plumber. There was a pressure boiler, modern boiler.

Mr. Thompson. I can only say that you water-works people wil have to work out your own salvation.

Mr. Gunther. You have some plumbing bills before the legislature at the present time, and if you could embody something in them which would protect the water-works men it would be a good thing.

The President. The only thing that has been suggested, as far as I know, that will protect the water-works men, is the check valve.

Mr. Frank E. Merrill.* There is no water meter made that will stand hot water. If hot water backs up from the house pipes into the meter it will damage it so that it will not register. I should like to ask the gentleman how he expects the water-works people to measure water if there is not a preventive for its coming back into the system.

Mr. Thompson. That is only occasionally. I do not think that you would ever receive enough to affect your meter to any extent.

Mr. A. R. Hathaway.† I just want to refer to the title of this paper, — "Relations between Plumbers and Water-Works Superintendents." I was just turning over in my mind the relation of plumbers to the water-works superintendents, and then the admission Mr. Thompson made that he doesn't know much about water meters. I was wondering if Mr. Thompson as well as the other plumbers would not make more of a study of the meters and perhaps learn a little more about them.

In connection with that, we had an experience in Springfield some time ago. In our new building code we have a plumbing inspector. He has taken some samples and used them in the evening school with some of his plumbers, got them together and given them instructive talks, explaining the workings of the water meter, and I think that we have seen good results in the relation of the plumber to the water-works superintendent.

Mr. Thompson. That is a splendid suggestion.

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* Water Commissioner, Somerville, Mass.

† Water Registrar, Springfield, Mass.

THE NEED OF UNIFORMITY IN PLUMBING REGULATIONS.

BY PROFESSOR GEORGE C. WHIPPLE, HARVARD ENGINEERING SCHOOL, CAMBRIDGE, MASS.

It is a popular idea, and I believe a true one, that plumbing costs more than it ought to. Yet the master plumbers say, and I believe they say truthfully, that as a class they are not getting rich. Apparently the excess profits, in so far as they may exist, are going chiefly into the hands of the great corporations which manufacture the plumbing materials. Trades unionism also tends to keep up labor costs in this branch of the building industry, as in all others. There are doubtless abuses in the plumbing business, as in other lines of business, which need correction, but they need not be considered here. We, as sanitary engineers, are more interested in finding out whether there are faults which it is in our own power to correct, whether our designs are more elaborate than they ought to be, whether the materials specified for the work are reasonable and proper. I believe that the subject of house plumbing has not received the attention it deserves from water-works men. The house piping is an integral part of a water-works system; the greatest waste of water occurs in the plumbing fixtures; the soil pipes are an integral part of the sewer system. Cities really have one great hydraulic system, with three separate parts which correspond to the arteries, capillaries, and veins of the circulatory system of the body.

Plumbing is a business regulated under the police power of the state. The regulations for the most part were made many years ago, at a time when it was believed that filth was the cause of certain diseases and that sewer gas was a poisonous substance. This idea of regulation was a perfectly justifiable use of the police power of the state in the interest of the health, morals, and safety of the people. I believe that it is still a perfectly justifiable use of the police power. But since the Massachusetts regulations were made, forty years ago, science has learned much in regard to the cause of disease. It has proved that the danger of diseases being spread by sewer air is very small indeed. On the other hand, it has learned that sewage is a very dangerous substance, that dangers to health lurk around the plumbing fixtures, where there is chance that minute particles of fecal matter may pass from one person to another by the method known as contact. Furthermore, foul odors influence health even though they may not cause acute and recognizable diseases. If, however, the dangers are less than was formerly supposed, it is reasonable that the factor of safety in plumbing designs should be correspondingly reduced in the in-

terest of economy. The importance of having ample facilities for using water is becoming more and more appreciated every year. Standards of cleanliness are rising. We need simpler plumbing, but we also need more plumbing.

In the early days regulations were left largely to local boards of health, and naturally a great variety of rules and methods of procedures were adopted. The better and more prosperous communities were inclined to improve on the regulations of their neighbors. Each little addition usually represented somebody's personal idea, and was not based on scientific knowledge. As a result, we find that at the present time the plumbing rules and regulations of the state are in a chaotic condition. Two cities have regulations based on special acts of legislature. Fifteen cities and towns have adopted the so-called State Examiners' Rules, and in these places the regulations are, therefore, uniform. Seventy-seven cities and towns have regulations made by local ordinances, and there are scarcely two of these which are exactly alike. In addition a few towns have what may be called informal regulations. About 260 towns, however, many of which are of considerable size and population, have no rules and regulations. These differing methods of control have resulted in a great variety of regulations. In many cases they appear to be unduly restrictive. Even within a short distance of Boston there are certain plumbing devices which are required in one place, prohibited in another, and left optional in a third. These differences appear to be quite unnecessary and accomplish no good purposes, serving merely to make trouble alike for architect, master plumber, and house owner, and tending, also, to increase the cost of plumbing, as both the architect and the plumber must take time to ascertain what regulations exist in any particular place.

The increased complexity of the regulation of the details of plumbing has resulted partly from the use of changed materials and new methods of installation of plumbing and house drainage, but it has been due also to changes in buildings themselves, their greater height, the increased number of multiple houses, and the increased number of plumbing fixtures in buildings. These regulations appear in most cases to be justifiable for certain classes of buildings, but when applied to other classes of buildings may be unnecessarily severe.

Of course there have been many changes in business and social conditions since the plumbing laws were established in Massachusetts, and even since they were last revised, in 1909. There has been a gradual change in the methods of doing plumbing work. Manufactured supplies distributed by large corporations have taken the place of much of the work done on the ground. Plumbing work in the house to-day is largely a matter of assembling manufactured products; but while this may require less skill on the part of a craftsman it will always require good judgment. Less work than formerly is done in the plumber's shop. A number of years ago, when cities were smaller, plumbers were engaged on the basis

of financial responsibility and personal reputation and acquaintance; but now that cities have become of large size this personal relation is being lost, and the public must apparently depend more and more upon the system of registration and licensing of plumbers and inspection of the work.

The public often complain of abuses in the plumbing business, of waste of time, of puzzling ideas as to who should do certain kinds of work, of quarrels between plumbers and steam fitters, of difficulties in the purchase of supplies except through master plumbers, and the like. It should be clearly borne in mind that plumbing regulations have little or nothing to do with these things. Business regulations and trades union rules should not be confused with official plumbing regulations.

The enforcement of the plumbing rules and regulations usually involves three steps: first, the issue of permits; second, the inspection of the work; and third, penalties for violations. In the case of cities and towns which have public water supplies or public sewers this system of permit and inspection appears to be necessary, but in the case of small towns it would appear to be less necessary, and the adoption of this system should be left for each community to decide. There is considerable variation in the practice of issuing permits, in the fees required for permits, and in the requirement of a statement, sketch or plan of work to be done. Uniformity in this matter of permit and inspection would facilitate the installation of plumbing and would be a benefit to the people, but it is a matter which to a considerable extent may be left to the local authorities. Where permits are required, they should be issued only to master plumbers.

On the whole, the inspection of plumbing at the present time appears to be carried on in a reasonably satisfactory manner, but there appear to be many cases of non-compliance with the law. The methods of securing compliance with the law at the present time are legal and necessitate court proceedings. The difficulty of this system appears to be that the penalty for violation of the regulation is one that cannot be physically put into effect. The suggestion has been made that the plumbing regulations should prohibit the use of water in a building, except for test purposes, until the plumbing has received approval. At the present time, the gas companies refuse to turn on the gas until inspection has shown that the gas piping is in proper condition, and this method operates satisfactorily.

Many of the present-day difficulties with plumbing cannot be solved by legislation unless concerted action can be obtained among the states. Plumbing supplies are now manufactured by large corporations doing business throughout the country, and it is impossible to regulate many of the details by a law passed in any one city or state. If regulations are too minute they have the result of increasing the cost of plumbing.

The troubles with plumbing are usually much less in new buildings than in old buildings. It is usually the old, worn-out plumbing which results in filthy and unhygienic conditions. Greater attention therefore

should be given to the re-inspection of plumbing already in use. Cheap materials and poor workmanship, however, hasten bad conditions, and it is largely for this reason that sound basic rules and regulations are necessary. Reinspection, which would naturally be a function of the local health department, should be confined to rented houses, which may some day be regarded as quasi-public buildings.

A study of the detailed plumbing regulations, especially those which relate to the subjects of trapping and venting, indicates that many of the regulations should be simplified for small dwellings used by a single family. In multiple dwellings of two or more stories, stoppages or leaks in one apartment may affect the occupants of another apartment, and greater factors of safety are necessary in such buildings than in buildings occupied by a single family. Simplification of the plumbing systems in small buildings will tend to reduce the cost of housing and eventually permit an increase in the number of fixtures installed without additional total expense. Increased opportunities for the use of water in the home will tend to improve the health conditions of the community. This result can apparently be brought about by classifying buildings according to height, occupancy, and use, and by making different regulations appropriate to different classes of buildings.

If the regulations are thus modified so as to provide simple rules for the small, low building occupied by a single family, with more complicated rules for the larger and higher buildings, it would appear justifiable to make these regulations uniform for all cities and towns of the Commonwealth. The best solution appears to be that of providing, first, simple *minimum requirements*, covering merely the most elementary matters of sanitation, state-wide in their application, and, second, other rules and regulations which may be known as the *standard regulations*, and which may be accepted in whole or in part by the local authorities, becoming effective after having been approved by the State Department of Public Health. Provision should be made for modifying these rules and regulations from time to time in order that advantage may be taken of progress in the art and that new devices which prove to be satisfactory may be used. In all cases the enforcement of the minimum requirements and the standard regulations should be in charge of the local authorities.

At the present time the water-piping systems which convey water to plumbing fixtures are not subject to supervision and inspection. This has resulted in unsatisfactory conditions. Plumbers usually install the water piping, the fixtures, and the drainage system as a single job. Competing plumbers therefore are inclined to cheapen the water piping, so that pipes of inferior quality and of insufficient size are installed. As a result the water pipes often become clogged and fail to supply water to the fixtures in the required volume or at the required pressure. The increased use of flush valves, which require water delivered at a high rate for a short time, is an illustration of the need of having the water piping as well as the

drainage system subject to inspection. The supply of water to the fixtures and its subsequent removal should obviously be regarded as a single problem. The possibility of pollution of water by improper connections in the piping system has been demonstrated in many cases. There is another serious problem found in domestic hot water supplies, — corrosion and over-heating not infrequently resulting in explosions, with danger to life and property. Of course, the pipes used for heating buildings by steam or hot water are not intended to be covered by the plumbing regulations.

Some of the most unhygienic conditions resulting from improper house drainage are found not in the cities but in rural districts, as, for example, in summer resorts. Greater attention should be given to such buildings in the interest of the public health. These troubles are not as closely related to the fixtures or the interior piping as to the manner of disposal of sewage and waste water. Local boards of health now have authority to control such conditions, but too commonly they are neglected. Better results would be secured if some of these matters were included under plumbing regulations.

On general principles I am opposed to the concentration of power in the federal and state governments. I have always stood for the advisory powers of the State Department of Public Health, as opposed to the assumption of absolute state control. I believe in the delegation of police power to local authorities, especially in matters which do not seriously affect the public health. Nevertheless, in order to secure that uniformity in the plumbing regulations which seems so desirable in the interest of economy, convenience, and, indirectly, in the interest of health, I see no other way than to have standards set up by the state. After more than a year's discussion of the subject by a special board, the membership of which included Edward C. Kelly, representing the State Association of Master Plumbers; Thomas M. Wilson, representing the New England Association of Plumbing Inspectors; Patrick J. Osborne, representing the Massachusetts Association of Journeyman Plumbers; James C. Coffey, representing the State Examiners of Plumbing, and the writer, representing the State Department of Public Health, a bill has been introduced into the legislature which, if passed, will make it possible for the State Department of Public Health, acting through a special board of supervisors, to clear up the present unsatisfactory situation with reference to the plumbing regulations. The bill does not involve sweeping changes in present methods. It provides for a board of five plumbing supervisors, three of whom shall act as plumbing examiners who will perform the duties of the present plumbing examiners. It provides for certain simple minimum requirements of the most elementary character, uniform throughout the state, but graded for different classes of buildings. It also provides for the setting up of a standard code of regulations which may be accepted in whole or in part by the local authorities. It provides that variations from

the standard shall not be permitted without the approval of the State Department of Public Health, but it also leaves it to each city or town to accept or reject these standard regulations in whole or in part, and in all cases it leaves it to each city and town to enforce the minimum requirements and the standard regulations, if adopted. This appears to be a fair and reasonable adjustment between state control and local control.

It is believed that the adoption of the proposed act and the formulation of minimum requirements and standard regulations as proposed therein will result in greater uniformity in the regulation of plumbing in the state; will make it possible to simplify the plumbing in small buildings and thus reduce their cost; will tend to increase the facilities provided for using water in buildings and thus improve the public health, and will be a substantial benefit to the people of the Commonwealth.

When we consider the almost total stagnation which now exists in the building industry, and the great shortage of houses of habitation, particularly in the cities, we are of the opinion that the opportunity to lessen the tremendous cost of building construction and to encourage a revival of industry is sufficiently apparent to warrant sympathetic consideration of this Association.

WATER DISTRIBUTION IN CONNECTION WITH PLUMBING AND ACTION OF WATER ON METAL.

BY DAVID A. HEFFERNAN.*

[*February 9, 1921.*]

Up to the present, water-works officials have concerned themselves with water supplies to residences and business buildings only as far as the point where the meter was set. This was the general practice, and there the responsibility ended. However, as I pointed out in my paper at Holyoke, we must realize that if we are to strive for the elimination of waste water and reduction of the costs of supply, we must make closer observation and have a more intimate knowledge of what becomes of the water after it leaves the meter.

We have also to pay more attention to water supplies in so far as their action on the medium of supply is concerned. We know that different kinds of waters act differently on different kinds of pipe. I quote from the Report of the Special Plumbing Board:

"1. Soft waters, especially if they contain carbonic acid, are more corrosive to metals than hard waters.

"2. Colored surface waters are usually more corrosive than colorless waters of the same degree of hardness.

"3. Ground waters are more corrosive than surface waters, partly because they generally contain larger amounts of carbonic acid, and partly because they do not form a slimy layer on the walls of the pipe.

"4. Filtered waters are more corrosive than the same waters unfiltered, because they do not form slimy layers in the pipes.

"5. Waters filtered by the process of mechanical filtration are more corrosive than waters filtered by slow sand filtration, because the use of alum increases the amount of carbonic acid in the water.

"6. Waters which are impregnated with sea water, or which have high chlorides and high nitrates due to pollution, are more corrosive than waters which do not contain these salts, because of their dissociation.

"7. Hot water is more corrosive than cold water.

"8. In any particular case one must balance the above-mentioned factors."

From this it is apparent that no set rule can be made to cover all cases, in so far as to recommend one kind of pipe to the exclusion of all others.

Milton gets its supply from the Metropolitan System, and of late we have been troubled with several service stoppages. In one case, that

* Superintendent Water Works, Milton, Mass.

of a service installed only eight years ago, the sidewalk stop was a $1\frac{1}{4}$-in. automatic drip valve with an iron body. In preparing to shut off the water it was found that the valve stem was broken. When it was dismantled we discovered that the stem must have snapped when the water was let on some years before, and the disks had not risen to their full height. The action of the water between the iron body of the valve and its brass disks had been strong enough to almost entirely close the passage through the valve body. In another case, we were changing a stopped meter in a house where strict orders were given by the owner's wife to our man "to be very careful not to allow any moisture to dampen the cellar floor." As he was removing the meter the cement-lined wrought-iron pipe gave way on the pressure side of the lever-handle cock, and not being prepared for the necessity of shutting off the water in the street, you may believe me not guilty of exaggeration when I say that the lady of the house was somewhat upset by the time the water had been shut off. Here, the wrought-iron service with the customary cement lining had been made into a brass ell. In some manner the action between the two metals had eaten them both until only a slight pressure was needed to separate them. Examination showed the ell to be nearly closed up at the end of the pipe in the ell, but a point at the curve of the ell was clear of rust and corrosion.

In the matter of lead pipe we had an experience that surprised me. A business building is supplied with a $\frac{5}{8}$-in. lead pipe, through which a very considerable amount of water passes for its size. We were notified of a stoppage. We had never had a stoppage in lead pipe before, and thought, at first, that the trouble must be where the brass corporation entered the cast-iron main, but this was not so. The only way the pipe could be cleared was by forcing through it, several times, a wad of tissue paper by means of a pressure pump. Nothing hard came out, just black, slimy grease.

We are now lining all our cocks with lead, which, we hope, will eliminate most of the trouble.

From these experiences it may be seen that the action of water on metals is one to which much earnest thought and study must be given if we are to forestall serious trouble later. In this connection, I am convinced that the failure of automatic devices, such as relief and vacuum valves, is due mostly to the action of the water. There are two ways of overcoming this evil. First, the use of pipe and fittings which will not be adversely acted upon by the water; second, the supplying of water which will not attack the pipe and fittings.

There is action between wrought-iron or steel pipe, whether or not galvanized, and brass fittings; between brass pipe and brass fittings. This latter is due to the fact that brass pipe contains 40 per cent. zinc and 60 per cent. copper, while brass fittings contain a lesser amount of copper and really show less signs of corrosion than the pipe.

This matter should be given our most serious consideration and discussion. In the meanwhile I feel that the hot and cold water supplies after they leave the meter should be placed in the new plumbing code, for the protection of house purchasers against unprincipled building speculators, for the advantage of master plumbers who now encounter different plumbing codes in nearly every city and town, and for water departments and companies which should benefit in the decrease of waste water from cheap defective fixtures now sometimes installed.

I can't understand how pipe under pressure of 100 lb. could get into that condition. I was there when the force pump was put on it and the tissue paper came through, and was surprised at the collection discharged and can't understand how that matter could adhere to the lead pipe under that pressure. The action of the pump, with 150 lb. pressure, forced the thing through.

DISCUSSION OF R. S. WESTON'S PAPER: "LEAD POISONING BY WATER."

[December, 1920, JOURNAL N.E. W. W. ASSN.]

BY GEO. C. BUNKER.*

In connection with Mr. Weston's instructive paper on "Lead Poisoning by Water, and Its Prevention," in the JOURNAL of this Association for December, 1920, some data obtained by the author during his studies of the water supply of Gatun, Canal Zone, may be of interest. The raw-water supply of this community is obtained from an impounded reservoir in which the run-off from a watershed area of 1 019 acres is collected. The geological formation underlying the watershed is known as the "Gatun." Mr. Donald F. MacDonald, the geologist, has written:

> "The Gatun foundation consists of three members, as follows: (*a*) About 500 ft. of marls and argillites, or clay rocks, and some beds of soft sandstone and conglomerate; this member is bluish-gray but locally contains many brown specks, indicating fragments of organic material; it is rich in the fossil shells of ancient marine life; (*b*) mostly fine, soft sandstone, about 100 ft. thick, containing a few fossils; (*c*) light to creamy gray indurated clay beds. The upper part of the formation weathers into red clay, and except where this is cut by streams it covers the solid rock to a depth of 10 to 25 ft."

As a result of this formation, the alkalinity of the water in this reservoir is low, 15.5 to 24.5 p.p.m., as $CaCO_3$.

The raw water is treated with aluminum sulphate, aërated, passed through sedimentation basins, and treated with lime; filtered through rapid sand filters and disinfected with liquid chlorine. There has been considerable variation in the chemical characteristics of the raw-water supply during the last five years, which renders the treatment of this water more difficult and expensive. For example, the solids have varied from 53 to 86 parts, the alkalinity from 13 to 21 parts, the soap hardness from 6.3 to 26 parts, the iron content from 0.30 to 3.00 parts, the color from 10 to 152 parts, the turbidity from 6 to 46 parts, and the oxygen consumed from 1.55 to 9.8 p.p.m.

The application of lime to the partially decolorized and settled water was started in the first quarter of 1916 because the continued low alkalinity of the raw-water supply of this plant, 14 to 20 p.p.m., with the amount of alum necessary for the removal of the color, produced conditions such that

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it was considered advisable and necessary to increase the alkalinity and decrease the amount of free carbonic acid in the filtered water by the addition of soda ash or lime. Due to the large amounts of chemicals required for the treatment of the raw water during 1916, it was not found feasible to neutralize all of the free carbonic acid in the settled water and maintain a small amount of carbonate (CO_3) alkalinity in it, as it flowed upon the filters, until the last month of the year.

In order to determine the action of the filtered water on lead, 25 ft. of a new 1-in. lead pipe, from the stock on hand, was connected to the 12-in. cast-iron pump discharge main, and laid on the ground. An ordinary brass faucet was placed on the discharge end. Water was turned into this pipe on February 1, 1918, and run continually through it with few exceptions, at the rate of about one gallon per minute from 8.00 A.M. to 5.00 P.M. each day. From 5.00 P.M. to 8.00 A.M. the water remained in the pipe without any circulation, except in a few cases where there was a slow dripping. At approximately ten-day intervals until August 10, 1919, samples were collected of the water standing overnight, and, one hour later, of the running water.

The average changes of temperature to which the water in this pipe was submitted were as follows:

TABLE 1.

TEMPERATURES OF WATER IN LEAD PIPE EXPERIMENT.

Date.	Time.	First Water Drawn Off. Temperature, Degrees Cent.	Time.	Running Water. Temperature, Degrees Cent.
March 22, 1917....	8.30 A.M.	26.7	12.30 P.M.	28.5
March 23, 1917....	7.30 A.M.	24.1	2.30 P.M.	27.2
March 29, 1917....	8.00 A.M.	23.5	3.00 P.M.	27.6
March 30, 1917....	8.00 A.M.	24.5	3.00 P.M.	27.5
April 5, 1917.......	9.00 A.M.	27.5	2.00 P.M.	28.5

Determinations of phenolphthalein alkalinity, erythrosine alkalinity, and lead were made on the samples; 2000 c.c. of the samples were evaporated to dryness and the lead determined by the method given in the 30th (1898) Annual Report of the State Board of Health of Massachusetts, pages 577–585. A tabulation of the analyses of 121 samples of water collected during the above period follows.

TABLE 2.

LEAD PIPE EXPERIMENT.

(Results expressed in parts per million.)

Date.	Carbonate (CO_3) Alkalinity.	Erythrosine Alkalinity as $(CaCO_3)$.	Lead.	
			Water Standing Overnight.	Running Water.
1918.				
February 1......	1.1	16.0	...	0.13
2......	1.1	16.0	0.15	0.25
3......	1.1	17.0	0.20	0.15
4......	1.1	16.0	0.27	0.37
5......	0.6	16.0	0.65	0.06
6......	0.8	17.0	0.37	0.20
7......	1.1	16.0	0.50	0.10
8......	1.5	16.0	0.35	0.15
9......	1.9	16.0	0.55	0.10
10......	1.1	16.0	0.50	0.12
20......	1.5	16.0	0.45	0.25
March 2......	1.1	16.0	0.32	0.12
12......	1.1	16.0	0.32	0.10
22......	1.7	15.0	0.25	0.05
April 1......	1.1	15.0	0.15	0.25
11......	0.6	15.0	0.30	0.15
21......	0.6	15.0	0.65	0.25
May 1......	0.6	15.0	0.22	0.12
11......	Trace.	16.0	0.12	0.12
21......	Trace.	15.0	0.35	0.15
31......	2.4	15.0	0.30	0.15
June 10......	1.2	18.0	0.55	0.60
20......	0.6	17.0	1.20	1.10
July 1......	1.2	18.0	0.15	0.10
10......	0.6	19.0	0.07	0.07
20......	0.6	16.0	0.15	0.07
31......	0.6	16.0	0.25	0.10
August 9......	Trace.	16.0	0.30	0.10
19......	Trace.	17.0	0.15	0.12
29......	Trace.	18.0	0.15	0.12
September 8......	0.6	18.0	0.25	0.10
18......	Trace.	18.0	0.10	0.07

TABLE 2. — *Continued.*

LEAD PIPE EXPERIMENT.

(Results expressed in parts per million.)

Date.	Carbonate (CO_3) Alkalinity.	Erythrosine Alkalinity as ($CaCO_3$).	Lead.	
			Water Standing Overnight.	Running Water.
1918.				
October 8......	0.6	15.0	0.10	0.10
18......	0.6	16.0	0.15	0.12
28......	0.6	16.0	0.22	0.20
November 7......	1.2	19.0	0.20	0.18
18......	Trace.	18.5	0.20	0.30
28......	0.3	19.0	0.25	0.20
December 17......	No report.	...	0.35	0.23
27......	0.9	19.0	0.15	0.20
1919.				
January 6......	1.2	21.0	0.20	0.15
17......	Trace.	19.5	0.12	0.10
27......	1.2	19.5	0.10	0.11
February 6......	1.2	18.5	0.15	0.10
17......	1.2	18.5	0.18	0.10
28......	1.2	19.0	0.12	0.10
March 20......	2.4	23.0	0.15	0.10
31......	2.4	21.5	0.12	0.10
April 10......	1.8	23.0	0.20	0.15
21......	4.2	22.0	0.30	0.12
30......	1.2	21.0	0.30	0.22
May 10......	2.4	22.0	0.22	0.20
20......	1.2	22.0	0.25	0.22
30......	1.2	20.5	0.20	0.15
June 10......	1.2	20.0	0.18	0.15
20......	1.2	18.5	0.25	0.18
30......	1.2	20.0	0.20	0.10
July 10......	1.2	21.0	0.18	0.12
20......	1.9	19.5	0.12	0.15
30......	1.9	20.5	0.18	0.12
August 10......	0.6	18.5	0.15	0.10

During the first ten days the amount of lead was determined each day. In the standing overnight samples it increased from 0.15 p.p.m. in the first sample to 0.65 p.p.m. in the fourth sample and then decreased slightly to 0.50 p.p.m. on the tenth day. In the running samples, the lead increased from 0.13 p.p.m. on the first day to 0.37 p.p.m. on the fourth day and then decreased to 0.12 p.p.m. on the tenth day.

After the tenth day the lead in the overnight samples fluctuated up and down during the period ending June 20, reaching the high figures of 0.65 and 1.20 p.p.m. on the respective dates of April 21 and June 20 and the low figure of 0.12 p.p.m. on May 11. From June 20, 1918, to August 10, 1919, the maximum lead content was 0.35 p.p.m. on December 30, 1918, and the minimum, 0.07 p.p.m. on July 10, 1918. As an average figure during this period, 0.20 p.p.m. may be taken.

After the tenth day the lead in the running samples fluctuated between 0.12 and 0.25 p.p.m. until June 10 and 20, 1918, when it reached 0.60 and 1.10 p.p.m., respectively. From the latter date until August 10, 1919, the lead varied from 0.07 to 0.23, but 0.14 p.p.m. may be taken as an average figure.

After the collection of the last samples, a section of the pipe was split open and the interior surface found to be covered with a very thin, light coating, — too thin in my opinion to prevent continued action of the water on the lead. In Fig. 1, sections are shown of this pipe and of a galvanized-iron pipe operated under similar conditions and over the same period of time. On account of the heavy deposit in the latter pipe, one would expect the formation of a thicker coating in the lead pipe than was found and is shown in the illustration.

As Mr. Weston has pointed out in the case of the Milford water, the aëration of the Agua Clara supply, with the accompanying increase in dissolved oxygen, undoubtedly increases the corrosive action of the water on lead pipes. Table 3 illustrates his statement at the top of page 253, about the oxygen being used up in water standing in a lead pipe.

TABLE 3.

SPECIAL DETERMINATIONS OF DISSOLVED OXYGEN IN SAMPLES OF WATER FROM A LEAD PIPE.

Date.	Sample.	Time.	Temperature, Degrees Cent.	Dissolved Oxygen.	
				Parts per Million.	Per Cent. Saturation.
March 22, 1917	Standing overnight.	8.00 A.M.	26.7	6.04	73.0
March 22, 1917	Running.	8.02 A.M.	26.8	7.79	96.0
March 30, 1917	Standing overnight.	8.00 A.M.	28.5	6.12	72.5
April 5, 1917	Standing overnight.	8.00 A.M.	25.3	6.35	76.1

Although the free carbonic acid was removed from the water running through the lead pipe by the lime treatment, carbonate (CO_3) alkalinity being present on fifty-two out of the sixty-one days on which samples were

Fig. 1. Coatings on Lead and Galvanized Iron Experimental Pipes.

collected, the action of the water on the lead was not stopped. Under these conditions the action of the filtered water with the chemical characteristics given in Table 4 must be due to its low hardness and alkalinity and to its rather high oxygen content, the combined influences of these factors overcoming the restraining effect of the hydroxyl ions.

TABLE 4.

SUMMARY OF CHEMICAL CHARACTERISTICS OF FILTERED WATER USED IN LEAD PIPE EXPERIMENT.

	Soap Hardness ($CaCO_3$).	Alkalinities.		Color.	Dissolved Oxygen.		Total Solids.	Nitrates.	Chlorides (Cl).
		Erythrosine ($CaCO_3$).	Carbonate (CO_3).		Parts per Million.	Per Cent. Saturation.			
Median...	20.8	16.3	0.6	2	7.1	90.7	75	Trace.	6.5
Maximum.	30.8	19.1	1.5	8	8.1	103.2	91	0.030	7.0
Minimum.	16.9	14.5	Trace.	0	6.0	77.4	63	0.000	5.5

Note: The soap hardness was determined weekly on a seven-day composite sample, the alkalinities were determined daily, and the dissolved oxygen on a catch sample collected each week.

In order to maintain the carbonate (CO_3) alkalinity, as summarized in Table 4 and as given in more detail in Table 2, lime was used as indicated in Table 5.

TABLE 5.

AMOUNT OF LIME APPLIED TO SETTLED WATER.

Month.	Pounds per Million Gallons.	Month.	Pounds per Million Gallons.
1918.		December	47
February	39	1919.	
March	39	January	47
April	50	February	61
May	40	March	51
June	39	April	67
July	30	May	48
August	51	June	47
September	50	July	56
October	56	August	51
November	48		

It must be remembered that the lime is used principally at this plant to raise the alkalinity of the water, and that it would be used even if there were no lead services in the district supplied by water from this plant, so the cost of this treatment should not be charged entirely to the prevention of plumbo-solvency.

Fig. 2 shows the slaking box for the unslaked lime which is shipped from the States either in steel drums or ordinary wooden barrels lined with tin. The milk of lime is lifted by an ejector into one of the duplicate steel tanks. From these tanks the diluted limewater flows into the concrete orifice tank, which carries a float valve to regulate the head over a steel plate in which there is a row of holes of varying sizes. The limewater is

divided into two equal portions, each of which flows through a galvanized iron pipe to one of the settling basins and runs into the settled water as it passes from the first to the second section of each basin. A water wheel is provided for turning the agitators in the tanks.

Pieces of sheet lead, measuring 1 in. long, ½ in. wide, and $^3/_{32}$ in. thick, were exposed to the action of the different waters, Nos. 1–7, inclusive, listed in Table 6. The settled water, with an alkalinity of 4.0 p.p.m., a soap hardness of 25.3 p.p.m., a free carbonic acid content of 6.8, and a

FIG. 2. SLAKING BOX, SOLUTION TANKS AND ORIFICE TANK FOR APPLYING LIME TO SETTLED WATER.

Ph value of 4.5 ±, dissolved 5.0 and 9.5 p.p.m. of lead, respectively, at the end of one and seven days. This represents the character of the filtered water which was discharged at times from the Agua Clara Plant before the use of lime was started. Samples of this class of water collected after standing overnight in a lead pipe of the same length and diameter as used in the experiment previously described, but prior to the start of the lime treatment, were found to contain from 0.3 to 2.33 p.p.m. of lead.

In order to obtain an idea as to the amount of carbonate (CO_3) alkalinity necessary to add to the filtered water in order to reduce the action of the latter on lead, Experiments 2 to 6, inclusive, were made. From these it is seen that the presence of 2.4 p.p.m. of carbonate alkalinity reduces the amount of lead dissolved from 5.0 and 9.5 p.p.m., respectively, at the end of one and seven days, to 1.0 and 1.7 p.p.m. The addition of

4.8 p.p.m. of carbonate alkalinity increases the action of the water on the lead during the first twenty-four hours, but retards it slightly during the seven-day period.

In the case of this water supply, the conclusion may be drawn from these experiments that a carbonate (CO_3) alkalinity of 2.4 p.p.m., produced by the addition of lime, must be maintained in order to keep the lead content of the filtered water, as drawn into houses through lead services during ordinary day use, below 0.1 p.p.m. However, from other experiments which I have made with lead pipe, I do not think this amount of alkalinity will always prevent the lead from rising above 0.1 p.p.m. in the water which stands in the services overnight. In the case of new lead services, even with this amount of alkalinity present, the lead may run as high as 0.50 p.p.m. during the first three months after their installation, and the consumers cannot be depended upon to always waste the first water drawn from the pipes in the mornings. Under the local conditions of operation of this plant, it is difficult to always insure the presence of a carbonate (CO_3) alkalinity of 2.4 p.p.m., so I am of the opinion that in order to avoid any ill effects, due to the consumption of lead, it is best to discontinue the installation of lead services in the district supplied by water from this purification plant.

As far as I can learn, no recognized cases of lead poisoning have occurred in this district, although as Mr. Gage has pointed out there may have been cases of ailments which were intimately connected with the use of water containing more than 0.1 p.p.m. of lead.

In Experiment 9, in Table 6, a sample of disinfected filtered water was collected, immediately after the addition of the liquid chlorine, so that when a portion of it was poured over the piece of lead the residual chlorine amounted to 0.24 p.p.m. By means of a blank, it was found that the chlorine disappeared in one hour and thirty-five minutes from the water. Neither this sample of water nor that used in Experiment 10, which contained a trace of residual chlorine, dissolved any more lead than the filtered water in Experiment 8, showing that the chlorine, in the amount present, did not increase the plumbo-solvency of the water.

Among the other experiments listed in Table 6 are some made with waters of high alkalinities and conductivities, the latter approximating the mineral contents.

In the list of "Some Additional References" in Mr. Weston's paper, the third one refers to a paper by H. Heap, "Study of the Action of Various Waters on Lead," which was published in the Journal of the Society of Chemical Industries, Vol. 32, No. 15, August, 1913. To those who may have occasion to make a study of the subject I recommend this paper as an excellent contribution, both for its review of work done by others and for the experimental work carried on by the author. A list of 28 references to other papers is included.

TABLE 6.—ACTIONS OF VARIOUS WATERS ON LEAD.
(Houston's Method.)

Source of Sample.	Reaction to Lacmoid.	Parts per Million. Alkalinity to Erythrosine.	Soap Hardness.	CO_2.	Lead Found in Water. One Day.	Seven Days.	Hydrogen-ion Concentration.	Conductivity.	Remarks
Agua Clara Purification Plant:									
(1.) Settled water, not treated with lime......	Acid.	4.0	25.3	6.8	5.0	9.5	4.5	70.6	No erosion.
(2.) Filtered and disinfected water, 1.2 p.p.m. CO_3 alkalinity..........	Alkaline.	16.3	42.6	....	2.0	2.5	7.4	93.6	No erosion.
(3.) Same as (2) with addition of lime to obtain 2.4 p.p.m. of CO_3 alkalinity..........	Alkaline.	17.3	45.3	....	1.0	1.7	7.9	106.0	No erosion.
(4.) Same as (2) with addition of lime to obtain 4.8 p.p.m. of CO_3 alkalinity..........	Alkaline.	19.3	47.9	....	2.0	1.5	8.6^{+}	111.5	No erosion.
(5.) Same as (2) with addition of soda ash to obtain 2.4 p.p.m. of CO_3 alkalinity.......	Alkaline.	20.4	43.9	....	1.2	2.0	8.0	98.1	No erosion.
(6.) Same as (2) with addition of soda ash to obtain 4.8 p.pm. of CO_3 alkalinity......	Alkaline.	23.1	45.3	....	1.8	1.5	8.6^{++}	107.0	No erosion.
(7.) Filtered and disinfected water from Mt. Hope Purification Plant..........	Alkaline.	40.8	43.9	2.6	1.5	1.2	7.2	98.1	No erosion.
Miraflores Purification Plant:									
(8.) Filtered water..........	Alkaline.	52.0	53.2	3.8	1.5	2.5	7.1	117.0	No erosion.
(9.) Filtered water after disinfection..........	Alkaline.	52.0	53.2	4.2	1.5	2.0	7.1	121.3	No erosion.
(10.) Filtered and disinfected water from wash-water tank..........	Alkaline.	52.0	53.2	3.8	1.5	2.0	7.2	121.3	No erosion.
(11.) Water supply of Cartago, Costa Rica.......	Alkaline.	65.3	61.4	19.0	1.8	3.2	7.4	146.1	No erosion.
(12.) Water from Thermal Spring, Cartago, Costa Rica..........	Alkaline.	885.0	468.5	132.0	1.2	1.5	7.3	2948.7	No erosion.
(13.) Water supply of San José, Costa Rica......	Alkaline.	57.1	54.6	5.8	1.8	1.5	7.4	107.4	No erosion.
(14.) Water supply of Port Limón, Costa Rica ...	Alkaline.	88.8	86.6	0.8	1.5	1.0	7.7	171.8	No erosion.
(15.) Santa Ana mineral water, Costa Rica.......	Alkaline.	829.8	516.0	720.0	1.0	2.1	7.1	2465.0	No erosion.
(16.) Mineral water from Miraflores dump, Canal Zone..........	Alkaline.	523.6	1060	4.4	2.0	2.5	7.5	4292.5	No erosion.
(17.) Distilled water..........	Neutral.	1.5	4.0	....	185.0	500.	4.8	1.7	Erosion.

Notes: Residual Cl: Sample 2 = 0.01 p.p.m.; Sample 7 = 0.01 p.p.m.; Sample 9 = 0.24 p.p.m.; which disappeared in one hour thirty-five minutes; Sample 10 = 0.01 p.p.m. Dissolved Oxygen: Sample 9 = 7.3 p.p.m.; 92.2 per cent. sat. Sample 10 = 7.4 p.p.m.; 93.1 per cent. sat. All erosions noted after samples stood seven days.

Average temperature of closet in which test tubes were stored was 26.3 degrees Cent.

Phenol red used as indicator for Ph determinations above 6.6; methyl red for those below 6.0.

The pieces of lead used in these experiments measured 1 x ½ x 3/32 in.

Mr. Gage's remarks show us in a striking manner that we must not consider our work as being satisfactorily finished by the delivery to the public of a clear, colorless water, free from disease germs. We must bear in mind that other influences, in addition to those due to bacteria, are at work to produce ill health. Outside of the New England States I venture to say that very little work has been done or is being done in the United States by chemists, either in the laboratories of water works or of state departments of health, to determine the corrosive properties of water supplies on lead pipe.

The cases which Mr. Gage cites to show the connection between rheumatism and the consumption of lead-carrying waters are so illuminating that one cannot pass lightly over them or eliminate them as freak cases. Mr. Gage can well afford to be called a crank when his interest in this subject has cleared up various cases of puzzling ailments.

Fully as interesting as the cures effected is the assistance which Mr. Gage is rendering to the physicians of Rhode Island. This is a public-health measure of great importance, and should be adopted in health department laboratories, both in cities and states.

After mailing this discussion to the Secretary of the Association, I received an abstract of a recent paper read by James E. Reade before the Institution of Civil Engineers of Ireland, from which the following two paragraphs were taken:

"Special attention should be directed by those responsible for public health to the existence of what may be called disguised or obscured plumbism, so that whenever a lowering of the general standard of health is observed, consideration should be given to the part played by the domestic water supply, as at least a possible contributory cause."

"The usual water analysis gives no indication of the plumbo-solvent or erosive character of the samples examined. Possibly water analysts might consider the feasibility of supplementing their reports in this respect. There are certain well-known channels of investigations regarding the sanitary quality of a water supply in which inquiry is always directed. It will probably be most convenient, at any rate in the case of a proposed new water supply, to carry on the quest for plumbo-activity simultaneously. But in all cases the objective will be to determine whether the water in question possesses permanently or periodically, or whether any circumstances exist which would justify a suspicion that it may at any time become capable of acquiring, that most undesirable property."

THE FLUSH VALVE.

BY GORDON M. FAIR.*

[*Read February 9, 1921.*]

The recent report of the Special Plumbing Board of the Massachusetts Department of Public Health calls to the attention of architects, engineers, and plumbers the important change made during the past few years in the flushing of water-closets by the introduction of the flush valve. The use of this device to replace the flushing of closets from cisterns that receive their supply of water at a slow rate through a ball cock should be of especial interest to water-works engineers because the flush valve is operated in closer connection with the water-distributing system and makes demands on it that have not had to be coped with in the past.

The flush valve, which is sometimes called a "flushometer," is an automatic, quick-opening and slow-closing valve, operated by means of a lever or a push-button and connected directly to the water-supply system. Three factors in its use are of interest:

1. The sanitary factor.
2. The economic factor.
3. The hydraulic factor.

Of these the hydraulic factor is by far the most important. In formulating regulations relative to the use of flush valves, however, the other two should not be neglected.

The Sanitary Factor.

Flush valves should be placed with care if the contamination of the water supply as a result of siphoning into the distributing system polluted water standing in the closet is to be prevented. Authorities that have formulated regulations for installing flush valves have decreed that the valve must be situated above the closet seat, in order to break, at the end of each flush, the hydraulic connection between water supply and closet contents. Even when the valve is placed in accordance with this ruling it may under certain conditions become possible to contaminate the water in the distributing system. If, for example, the closet were clogged to such an extent that the water level were high enough to seal the rim from which the bowl is flushed, or if in the case of a siphon jet closet the rim had become clogged by impurities carried in the water, it might be

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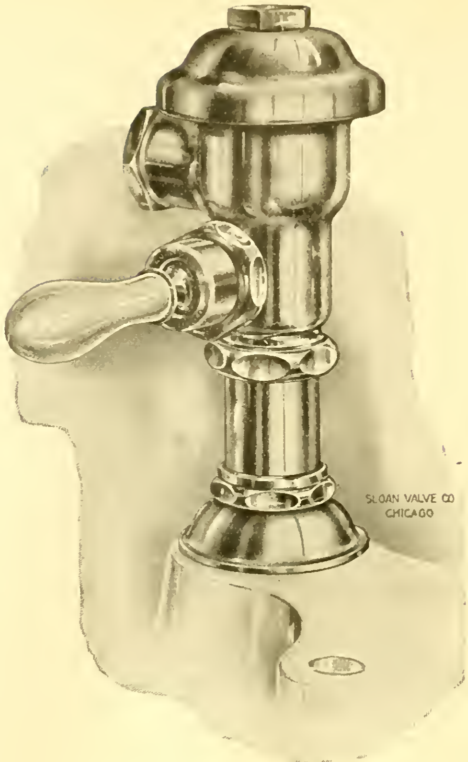
SLOAN VALVE CO
CHICAGO

Fig. 1.

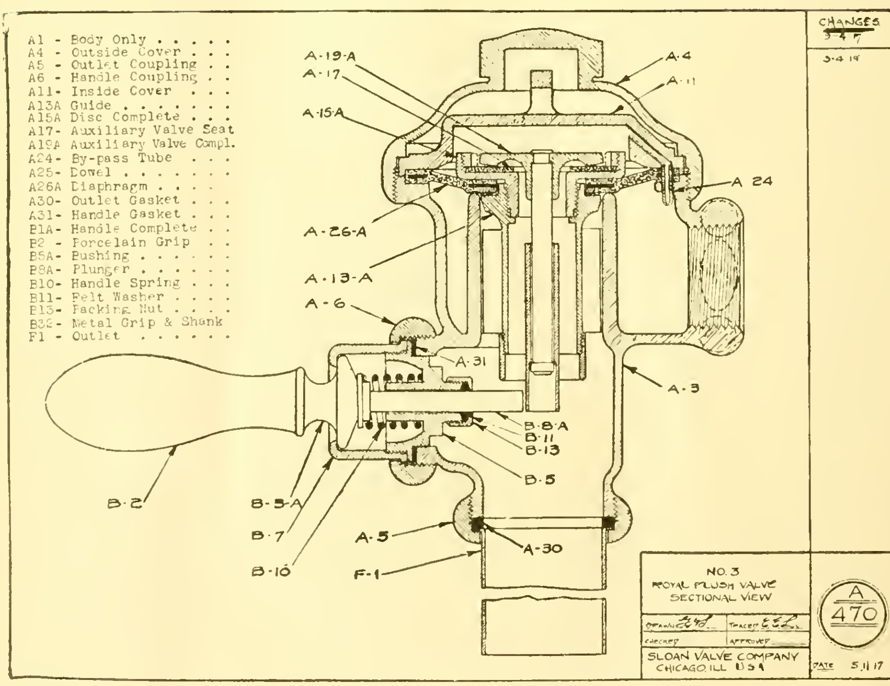
A1 - Body Only . . . . .
A4 - Outside Cover . . .
A5 - Outlet Coupling . .
A6 - Handle Coupling . .
A11- Inside Cover . . .
A13A Guide . . . .
A15A Disc Complete . . .
A17- Auxiliary Valve Seat
A19A Auxiliary Valve Compl.
A24- By-pass Tube . . .
A25- Dowel . . . .
A26A Diaphragm . . . .
A30- Outlet Gasket . . .
A31- Handle Gasket . . .
B1A- Handle Complete . .
B2 - Porcelain Grip . .
B5A- Bushing . . . . . .
B8A- Plunger . . . . . .
B10- Handle Spring . . .
B11- Felt Washer . . . .
B13- Packing Nut . . . .
B32- Metal Grip & Shank
F1 - Outlet . . . . . .
A-19-A
A-17
A-15-A
A-4
A-11
A 24
A-26-A
A-13-A
A-6
A-31
A-3
B-8-A
B-11
B-13
B-5
B-2
B-5-A
B-7
B-10
A-5
A-30
F-1
CHANGES
3-4-19
NO. 3
ROYAL FLUSH VALVE
SECTIONAL VIEW
SLOAN VALVE COMPANY
CHICAGO, ILL. U.S.A.
A
470
DATE 5.1.17

Fig. 2.

possible by operating a fixture on a lower floor to siphon the contents from the closet into the distributing system. The conditions necessary to bring about such an occurrence may seem strange and extraordinary, but they constitute a potential danger and should not be neglected in the design of the distributing system. In the light of these possibilities, the cistern or tank system seems safer; in other sanitary respects, however, the flush valve has advantages over the tank system. For example, the flush valve is again ready for use immediately after the flush is completed, whereas several minutes elapse before the cistern is filled. The valve, too, is more substantial in construction and less liable to get out of order. These advantages should result in the avoidance of the unsightly conditions often encountered when one flush is not sufficient to empty the closet or when the flushing device is out of repair.

The Economic Factor.

When the writer first undertook the study of the flush valve, he believed that both the first cost and the cost of operation of flushing devices might be in favor of the flush valve. As shown below, however, the first cost is influenced by hydraulic considerations to such an extent that the installing of flush valves is usually quite as expensive and in some cases even more expensive than the installing of cisterns, not because of the difference in cost of the flushing device proper but because of the difference in the cost of the piping necessary to supply them with water. The cost of operating flushing devices, on the other hand, is not dependent upon their hydraulic properties but upon the construction of the closet which they are supposed to flush. Each closet, it seems, has an optimum rate and amount of flush which may vary from $3\frac{1}{2}$ gal. in ten seconds, or a rate of 21 gal. per minute, to 3 gal. in four seconds, or a rate of 45 gal. per minute. The total delivery of a flush lies usually between 3 and 4 gal., with an average rate of about 25 gal. per minute. It is claimed that some closets can be flushed with as little as $1\frac{1}{2}$ gal. in one second. Even if this be admitted, it is easily seen that unless there is a large and continuous discharge of water from other fixtures a volume of $1\frac{1}{2}$ gal. of water is not sufficient to carry the waste material with adequate flushing through soil stack and house drain to the sewer. Plumbing regulations, therefore, usually prescribe a minimum flush of 3 to 6 gal. The rate of flow of $1\frac{1}{2}$ gal. in one second, or 90 gal. per minute, is also excessively high and requires a very large and uneconomical piping system. It is therefore improbable that water will be conserved by using flush valves and high rates of flow through long lines of pipe instead of cisterns that are filled slowly and discharge rapidly through a relatively short line of pipe.

The cost of keeping the flush valve in repair, however, should be small, because the mechanism of the flush valve is simple and strong. There is little chance of the valve getting out of order; the only part that

requires attention is the by-pass, which is narrow and easily clogged with foreign matter or rust. Red lead or other jointing material, used in connecting up the original piping system or in making repairs, is often a nuisance in this respect and makes it necessary to flush the system thoroughly before attaching the valve. In order to facilitate inspection of the valve, the device is usually equipped with a stop valve which permits the water supply to be cut off at the fixture. In some designs this stop valve also serves to regulate the quantity of water passing through the valve by being adjusted to throttle down the operating pressure to a desired value.

The Hydraulic Factor.

As stated above, the hydraulic factor of the flush-valve problem is by far the most important one. It may be considered under two headings:

1. The hydraulics of the flush valve proper.

2. The influence of the use of the flush valve on the hydraulics of the water-distributing system.

The hydraulic properties of the flush valve itself are established by the design. Six different types of valves have come to the writer's attention.

1. The water-operated diaphragm-type, fully-automatic valve without regulating mechanism.

2. The water-operated plunger-type, fully-automatic valve without regulating mechanism.

3. The water-operated plunger-type, fully-automatic valve with regulating mechanism.

4. The water-operated plunger-type, semi-automatic valve with regulating mechanism.

5. The water-operated plunger-type, semi-automatic valve without regulating mechanism.

6. The air-operated plunger-type, semi-automatic valve with regulating mechanism.

A fully automatic valve is one that discharges a constant amount of water and closes even when an attempt is made to prolong the flush by continuing to press down the lever or push-button that activates the mechanism, whereas a semi-automatic valve continues to discharge water until the lever or push-button is released.

A water-operated valve provided with a regulating mechanism is one in which the time of closing can be controlled by changing the size of the by-pass leading from the pressure side of the valve to the chamber beyond the piston head or diaphragm. When the valve is put into operation a jet or stream of water passes through this aperture into the chamber, gradually builds up sufficient pressure in the same, and forces the piston head or diaphragm upon its seat. In the fully automatic valve this

regulating mechanism controls the length of flush; in the semi-automatic valve it controls merely the rapidity of closing or the "refill" after the lever or button has been released.

An air-operated valve provided with a regulating mechanism finally is one in which the time of closing can be controlled by regulating the size of an aperture that permits air to escape from a chamber into which it is sucked when the valve is put into operation.

At the suggestion of Prof. George C. Whipple and through the courtesy of flush-valve manufacturers, seven different makes of valves were tested by Mr. Stanley T. Barker and the writer for the following properties, in the Laboratory of Sanitary Engineering of Harvard University:

1. Quantity of water delivered at various pressures
   (*a*) for flushing the closet
   (*b*) for refilling the closet with water after the flush is completed. (This quantity is known as the "refill.")
2. Rate of flow of water at various pressures.
3. Water hammer.

The results of these tests are shown in Tables 1 to 8.

TABLE 1.

VALVE A.

1-IN. DIAPHRAGM-TYPE, WATER-OPERATED, FULLY-AUTOMATIC CLOSING DEVICE WITHOUT REGULATING MECHANISM.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	2.6	9.5	.2	4.0	2.8	13.5	16.4
10	2.9	8.0	.1	3.0	3.0	11.0	21.7
15	2.9	6.5	.1	2.5	3.0	9.0	26.8
20	3.0	6.0	.1	2.5	3.1	8.5	30.0
25	3.0	5.0	.1	2.0	3.1	7.0	36.0
30	3.0	4.5	.1	2.0	3.1	6.5	40.0
35	3.0	4.5	.1	2.0	3.1	6.5	40.0
40	3.0	4.0	.1	2.0	3.1	6.0	45.0
45	2.9	4.0	.1	2.0	3.0	6.0	43.5
50	2.9	4.0	.1	2.0	3.0	6.0	43.5
55	2.9	4.0	.1	2.0	3.0	6.0	43.5

TABLE 2.

Valve B.

1-in. Plunger-Type, Water-Operated, Fully-Automatic Closing Device.

Regulating mechanism set to give maximum discharge at each pressure.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	4.9	13.0	1.3	22.0	6.2	25.0	22.6
10	4.0	7.5	0.7	10.5	4.7	18.0	32.0
15	2.9	5.0	0.4	5.5	3.3	10.5	34.7
20	1.7	3.0	0.2	3.0	1.9	6.0	34.0
25	0.6	2.0	0.1	1.0	0.7	3.0	18.0

TABLE 3.

Valve C.

1-in. Plunger-Type, Water-Operated Closing Device (Fully-Automatic only at Moderate to High Pressures) Without Regulating Mechanism.

Operating device held open for 1 second at low pressure.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	2.4	5.0	0.1	3.0	2.5	8.0	28.8
10	2.2	3.0	0.1	2.0	2.3	5.0	44.0
15	1.9	2.5	0.1	2.0	2.0	4.5	45.6
20	1.7	2.0	0.1	2.0	1.8	4.0	51.0
25	1.6	2.0	0.1	1.5	1.7	3.5	48.0
30	1.5	1.5	0.1	1.5	1.6	3.0	60.0
35	1.4	1.5	0.1	1.5	1.5	3.0	56.0
40	1.4	1.5	0.1	1.5	1.5	3.0	56.0
45	1.4	1.5	0.1	1.5	1.5	3.0	56.0
50	1.4	1.5	0.1	1.5	1.5	3.0	56.0

TABLE 4.

Valve D.

1¼-In. Plunger-Type, Air-Operated, Semi-Automatic Closing Device.

Regulating mechanism set to give maximum discharge (screw in 9½ turns) and minimum discharge (screw in 3 turns) respectively.

Operating Pressure. Lbs. per Sq. In.	Rate of Flush before Releasing Handle. G.P.M.	Discharge after Releasing Handle.		Time of Discharge. Sec.	
		Max. Gal.	Min. Gal.	9½ Turns.	3 Turns.
5	25.2	12.6	0.1	77	1.0
10	36.0	12.2	0.1	69	1.0
15	46.8	11.9	0.1	63	1.0
20	55.5	11.7	0.1	60	1.0
25	61.9	11.6	0.1	56	1.0
30	67.0	11.5	0.1	54	1.0
35	72.0	11.4	0.1	52	1.0
40	74.3	11.4	0.1	51	1.0
45	77.9	11.3	0.1	50	1.0
50	80.0	11.3	0.1	50	1.0
55	81.5	11.3	0.1	50	1.0

TABLE 5.

Valve E.

1¼-In. Plunger-Type, Semi-Automatic Closing Device Without Regulating Mechanism.

(Operating device held open for 1 second.)

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	3.7	5.5	0.6	6.0	4.3	11.5	40.4
10	3.8	5.0	0.6	5.0	4.4	10.0	45.6
15	4.0	4.0	0.6	5.0	4.6	9.0	60.0
20	4.1	3.5	0.5	5.0	4.6	8.5	70.3
25	4.1	3.5	0.5	4.0	4.6	7.5	70.3
30	4.2	3.0	0.5	4.0	4.7	7.0	84.0
35	4.2	3.0	0.5	3.5	4.7	6.5	84.0
40	4.2	3.0	0.4	3.0	4.6	6.0	84.0
45	4.3	3.0	0.4	2.5	4.6	5.5	86.0
50	4.3	3.0	0.4	2.5	4.6	5.5	86.0

TABLE 6.

VALVE F.

1¼-IN. PLUNGER-TYPE, SEMI-AUTOMATIC CLOSING DEVICE WITH
(*A*) REGULATING MECHANISM SET TO GIVE MAXIMUM DISCHARGE (SCREW OPENED ½ TURN).

Operating device held open for 1 second.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	4.4	8.0	0.2	4.0	4.6	12.0	33.0
10	4.6	6.5	0.2	2.0	4.8	8.5	42.5
15	4.6	5.5	0.2	2.0	4.8	7.5	50.2
20	4.7	4.5	0.2	1.5	4.9	6.0	62.7
25	4.7	4.0	0.2	1.5	4.9	5.5	70.5
30	4.7	4.0	0.1	1.0	4.8	5.0	70.5
35	4.7	3.5	0.1	1.0	4.8	4.5	80.6
40	4.7	3.5	0.1	1.0	4.8	4.5	80.6
45	4.7	3.5	0.1	1.0	4.8	4.5	80.6
50	4.7	3.5	0.1	1.0	4.8	4.5	80.6
55	4.7	3.0	0.1	1.0	4.8	4.0	94.0

(*B*) REGULATING MECHANISM SET TO GIVE MINIMUM DISCHARGE (SCREW REMOVED).

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	1.6	4.0	0.1	1.5	1.7	5.5	24.0
10	1.9	3.0	0.1	1.0	2.0	4.0	38.0
15	2.0	2.0	0.1	1.0	2.1	3.0	60.0
20	2.1	2.0	0.0	1.0	2.1	2.0	63.0
25	2.1	2.0	0.0	1.0	2.1	2.0	63.0
30	2.2	2.0	0.0	1.0	2.2	2.0	66.0
35	2.2	2.0	0.0	1.0	2.2	2.0	66.0
40	2.2	2.0	0.0	1.0	2.2	2.0	66.0
45	2.2	2.0	0.0	1.0	2.2	2.0	66.0
50	2.2	2.0	0.0	1.0	2.2	2.0	66.0

TABLE 7.

Valve G.

1½-In. Plunger-Type, Semi-Automatic Closing Device with (A) Regulating Mechanism Set to Give Maximum Discharge (screw opened ¼ turn).

Operating device held open for 1 second.

Operating Pressure. Lbs. per Sq. In.	Flush. Gal.	Time. Sec.	Re-fill. Gal.	Time. Sec.	Total Flow. Gal.	Time. Sec.	Rate of Flush. G.P.M.
5	10.5	13.0	1.1	7.0	11.6	20.0	48.5
10	10.6	8.0	.9	5.0	11.5	13.0	79.5
15	10.7	7.0	.8	5.0	11.5	11.0	91.8
20	10.8	6.0	.8	3.5	11.6	9.5	108.0
25	10.8	5.5	.6	3.0	11.4	8.5	118.0
30	10.9	5.0	.6	3.0	11.5	8.0	131.0
(*B*) Regulating Mechanism Set to Give Minimum Discharge (screw removed).							
10	4.7	4.0	.2	3.0	4.9	7.0	70.5
15	5.0	4.0	.2	2.0	5.2	6.0	75.0
20	5.2	4.0	.2	1.5	5.4	5.5	78.0
25	5.3	3.5	.2	1.5	5.5	5.0	90.8
30	5.4	3.0	.2	1.5	5.6	4.5	108.0
35	5.5	3.0	.2	1.0	5.7	4.0	108.0

TABLE 8.

Water Hammer Caused by Flush Valves.

Type of Valve.	Remarks.
A	Very little water hammer at all pressures.
B	Considerable water hammer at high pressures.
C	Very little water hammer at all pressures.
D	Water hammer depends upon adjustment of regulating mechanism.
E	Considerable water hammer at higher pressures.
F	Water hammer depends upon adjustment of regulating mechanism.
G	Water hammer depends upon adjustment of regulating mechanism.

A study of these tables leads to the following conclusions. Of the fully automatic valves only those valves (A and C) that were not provided with a regulating mechanism were successful. It is not known what was the matter with the valve in which the time of closing could be regulated (Valve B), and no claim is made that it is representative of its class. Valve C, which like Valve A delivered fairly constant quantities of water at all pressures and at quite uniform rates, seems to have been designed for the flushing of urinals, because the volume of flush is hardly sufficient for water-closets. Both of these valves closed slowly even under high pressures, as evidenced by the absence of water hammer.

Valve D, which is air-operated, and the water-operated Valves F and G are semi-automatic. By adjusting the regulating mechanism controlling the closing rate of these valves and by setting the stop valve in the proper position, it is possible to obtain from them practically any desired quantity and rate of flush, providing the length of time that the lever or button is pressed is accurately gaged. This constitutes a considerable advantage over the fully automatic valves. On the other hand, the operating mechanism of these valves may be kept open *ad libitum*, a condition that may entail either a considerable waste of water or an unsatisfactory flush, whenever the length of time that the lever or button is pressed is not accurately gaged by the user.

Excessive water hammer can be avoided in these valves by a proper regulation of their time of closing.

Valve E, the semi-automatic valve without a regulating mechanism, finally has the objection of giving rise to a considerable water hammer at the higher pressures. This, however, may be cut down by decreasing the pressure through a proper setting of the stop valve. The discharge volume per unit of time of operation is evidently quite constant at varying pressures, so that any desired flush may be obtained from this valve if the time of operation is well gaged, a condition that is subject to the same criticism as above. Unfortunately, lack of time did not permit an investigation of the means used by plumbers to avoid water hammer in pipe systems supplying water at the high velocities often employed in flush-valve installations. Theoretically, however, the common practice of providing air chambers at the end of the line is open to criticism. These air chambers are generally merely extensions of the supply pipe beyond the last fixture, and no provision is made to replace the air absorbed by the water or lost in other ways. Of course it is possible to place a gate valve at the entrance to the air chamber and to provide the chamber with two pet cocks. By closing the gate valve and opening the pet cocks the air cushion can then be re-established. An arrangement such as this needs attention from time to time, and is, therefore, subject to the objection that it brings in the human factor into an otherwise mechanically automatic problem. It is the writer's opinion, however, that, by a proper

setting of flush valve and stopcock, water hammer can be decreased more efficiently than by any other means.

It is evident that fixtures working at as high rates of flow as flush valves require a well-planned arrangement and size of supply piping to insure successful operation. At the present time there are three systems in common use for piping water to flush valves.

1. The direct-pressure system.
2. The gravity tank system.
3. The pressure-tank system

In the direct-pressure system the water is taken either from the service connection to the street main or from a separate connection made specially for this purpose and independent of all other fixtures in the building. It is a scheme that can be made to work successfully wherever it is possible to secure a connection to the water main that is large enough to permit employing pipe sizes proportioned in accordance with the demands of the flushing device. However, it is interesting to note that the connections specified by water departments are generally too small. A $\frac{3}{4}$-in. service pipe, for example, can deliver water to a flush valve at a rate of about 15 g.p.m. provided a city pressure of 40 lb. per sq. in. is available and the length of piping, including the customary allowances for bends, does not exceed 100 ft. As against this, a single flush valve (see Tables 1-7) discharges water at a rate of 25 to 40 g.p.m. and thus consumes all the water that under the conditions assumed can be conveyed to it in a one-in. pipe, providing the same does not supply any other fixtures. This fact usually excludes to all but the large consumers such as hotels, office buildings, and school houses the use of flush valves on the direct-pressure system. To be successful, furthermore, systems supplying valves for which the discharge rate and quantity vary with the water pressure must be equipped with a pressure regulator or other device that will keep the pressure constant. Only where high and constant city pressures are available may the required size of piping become small and therefore economical enough for small consumers. The direct-pressure system may then be used to advantage in communities in which the sevices are not metered. This proviso must be made because the smallest size meter that can deliver water to a single flush valve at an average rate of 30 g.p.m. with a loss of head of about 5 lb., for example, is a $1\frac{1}{4}$-in. meter. At this rate, two flush valves would require a 2-in. instrument. Meters of these sizes are, of course, absurdly large for services that could normally be gaged by a $\frac{5}{8}$-in. instrument. Even if large meters could be installed economically, it must be remembered that the amount of unregistered water, which for a given low flow is greater for a large meter than a small one, would increase to the disadvantage of the water department's revenue.

The writer may seem to discourage the use of flush valves on direct-pressure systems for small consumers, but he does not want to give the impression that this system cannot be employed successfully by large

consumers whose large service connections are equipped with large meters. The gravity-tank system and the pressure-tank system avoid some of the objections to the use of flush valves in connection with small systems. The gravity-tank system employs an open tank placed at as high a point as possible in the building. Water is supplied to it at a slow rate through a ball cock or some other device that will keep the water level of the tank at some constant height. From the tank, piping properly proportioned to secure the effective operation of the flush valve leads to the closet. The elevation of the tank is usually such as to give a pressure of at least 5 or 10 lb. at the fixture. The required size of tank varies with local conditions. For a school or factory, for example, in which a large number of fixtures is used during a comparatively short interval of time an allowance of 6 gal. for each water-closet and two gal. for each urinal is sometimes recommended. This corresponds to a per capita allowance of 0.3 to 0.5 gal., and varies with the size of the establishment, a smaller per capita allowance being made with increasing number of people. A minimum tank capacity of 25 gal. is desirable, and it is of course assumed that the larger the tank the larger will be the ball cock controlling the water level.

Unfortunately, open tanks are apt to accumulate dust, rust, organic growths, and other foreign matter which may clog the by-pass of the flush valve. Tank and ball cock also must be protected against freezing and otherwise need attention from time to time. The work connected with the care of one of these tanks may seem small, but this circumstance makes efficient supervision perhaps all the harder.

For these reasons pressure tanks that can be erected in any convenient part of the building where they are protected from the cold are sometimes substituted for the gravity tanks. In the pressure-tank system the service pipe entering the building usually divides in the cellar; one branch leads up to the pressure tank and the flush valves, and the other branch supplies the remaining fixtures. A check valve is inserted in the flush-valve piping at the juncture with the main supply pipe. The only disadvantage of this system compared with the gravity supply lies in the operation of the valves under a falling head. Valves that discharge the same quantity of water under all pressures here find their most effective use. Otherwise the pressure-tank system shares with the gravity-tank system most of the advantages over the direct-pressure system. Its influence on meterage, however, is perhaps open to objection.

The size of piping necessary to feed various numbers of flush valves can readily be computed by an engineer, providing he knows the city pressure at the building. It is not as easily done by a plumber. For this reason manufacturers have evolved various schemes for presenting the necessary information in a simple way. Each scheme, of course, takes into account the hydraulic characteristics of the particular valve, and it is hardly possible to lay down any general rules that will suit all valves on the market. The necessary data, however, could be presented in a

table showing the amount of water delivered by pipes of various size and of different length discharging under a pressure of at least 5 to 10 lb. into the flush valve. Such tables are commonly found in plumbing catalogues, and there is no necessity for reprinting in this paper a table such as the author has in mind.

Summary.

In conclusion, the points of this paper that should interest water-works engineers most may be summarized as follows:

1. Unless carefully placed in a well-designed distributing system the use of the flush valve may result in contamination of the water supply.
2. There is little reason to believe that water will be conserved by the use of the flush valve.
3. The installing of flush valves is only economical in large buildings.
4. The effect of the use of flush valves on water meterage and water hammer needs investigation.
5. The choice of the type of distributing system should be made only after the type of flush valve that will be used has been determined.

A consideration of this summary suggests to the writer another point that should be of interest to water-works men not only in connection with the use of the flush valve but in connection with the plumbing of buildings as a whole. This point is taken up in the report of the Special Plumbing Board of the Massachusetts Department of Public Health, on page 54 and following. The present status of the distribution of water within buildings is here called to the attention of engineers, who after reading this section of the report perhaps will agree with the statement that "there are good reasons why a sanitary code should include the water-distribution systems as well as the drainage system."

Discussion.

Mr. Frank E. Merrill.* I should like to ask the gentleman if he has any data in regard to the amount of water hammer caused by the ordinary flush valve.

Mr. Fair. That all depends upon the setting and how the flush valve is arranged. There is no reason why the flush valve should give any water hammer at all. If badly arranged, of course, there will be water hammer. And the amount of water hammer varies greatly with the flush valve used. There are certain flush valves that give high water hammer if the pipe is not well arranged and the stop-valve well set. By using the stop-valve you can cut down the pressure so that the water hammer will be decreased.

* Water Commissioner, Somerville, Mass.

Mr. A. W. F. Brown.* I think the use of flush valves is very detrimental to the water works. There has been severe water hammer where they were installed by plumbers who are A1, so far as I know. I had a water-gage knocked out in my office and felt a distinct tremor in the floor. There are three valves, supplied by a 2-in. pipe, running into a 1-in. with 80 lb. pressure behind it. I do not see any advantage over the tank closet, which will operate, if it gets water, within a reasonable time. The extra cost over the ordinary service is perhaps over a hundred per cent, because when they come into general use, and are used by the hundreds or thousands, it means that the 1-in. and $\frac{3}{4}$-in. services must be cleaned out and replaced by larger services.

Mr. G. Wilbur Thompson.† I have obviated water hammer in several cases by putting in a large air chamber, perhaps 4 or 5 ft. long, made out of 2- or $2\frac{1}{2}$-in. pipe, close by the meter, and also put a drip cock, or a little pet cock, right in the top. In case the action is something like an hydraulic ram, the pressure of the water will force out the air. In this same way the water will fill this chamber, but by putting in a draw-off cock below, and the little vent at the top, you can run the water out very quickly.

Mr. Brown. I have tried it, and in about a week or two there won't be any air there; the water will take up the air under a heavy pressure.

Mr. Thompson. That may be true; but if it was absolutely tight it ought to last longer than that, because an hydraulic ram will go sometimes for months before it exhausts all the air in the chamber.

Mr. David I. Heffernan.‡ I had one of those installations on a large service. In regard to small services, 1 in. in size, I have seen installations of the flushometer which I thought was a very good scheme. That was to place a pressure tank over the closet itself, over the flushometer. The one I am speaking of was made out of wrought-iron pipe. This flushing device works satisfactorily by having what we call the utility tank to resist any pressure. It holds about 3 gal. above the amount of water required to operate the flushometer. That was on an inch service. In this house are four or five bathrooms, and it gives perfect satisfaction.

Mr. Thompson. It seems to me if the tank only holds 3 gal. and is under pressure, that when the water comes down to the closet, the tank is refilling just as fast. When the valve closes you have got no air check there or cushion for that to rebound on, whereas in an air chamber you would have.

Mr. Heffernan. Yes, true enough.

However, it is a homemade affair and gives perfect satisfaction.

* Registrar and Superintendent Water Works, Fitchburg, Mass.

† President of Mass. Association of Master Plumbers.

‡ Superintendent Water Works, Milton, Mass.

REPORT OF COMMITTEE ON RAINFALL AND RUN-OFF MEASUREMENTS.

March 25, 1921.

The New England Water Works Association,
715 Tremont Temple, Boston, Mass.

Gentlemen. — This committee was appointed in December, 1918, "to consider the collection and standardization of rainfall and run-off measurements." Mr. William T. Barnes was chairman of the committee until March, 1920, when he resigned, owing to his removal from New England, and was succeeded by the present chairman.

Three meetings of the committee were held in 1918 and 1919, one jointly with the Boston Society of Civil Engineers' Committee on Run-off. At these meetings a program of work to be undertaken by the committee was definitely outlined, and this program has been stated in the progress report of the committee by Mr. Barnes, rendered September 22, 1919.

During the present year the work done by the committee has consisted merely in carrying out this program in the matter of collecting and preparing for publication certain available records of stream flow and rainfall. The character of the records to be included in its report, and the proper form of publication of same, was given extended consideration by the committee, and the following conclusions were reached:

(1) It was deemed advisable to bring down to date such of the reports of the yield of smaller New England drainage basins published in the report of the Committee on Yield in 1914 as are available.

(2) To collect and publish such additional records of yield of similar water-works drainage basins in New England and New York as are available.

(3) Inasmuch as they are generally available in printed form, it was deemed advisable not to include records for streams which are published in the annual water supply papers of the U. S. Geological Survey.

(4) Each published record to be accompanied by as complete a statement as possible of the conditions affecting the accuracy of the record and the yield of the drainage basin.

(5) It was decided to follow generally the form of publication used by the committee of 1914 in the preparation of data, both for the sake of comparison of the later records with those formerly published, and for the reason that many water-works superintendents use substantially the same form in the publication of run-off data in their annual reports. In this

connection it was decided, after full discussion, to present the data in the form of monthly values by calendar years, leaving the person desiring to apply the data to re-arrange it in water or hydrologic years, according to his own liking.

(6) The committee deems it its duty to compile at present for publication, in such a form as to give a permanent record, fundamental or original data only. The committee has not, therefore, undertaken an analysis of the records or deductions therefrom.

In the report of the Committee on Yield of Drainage Areas in 1914, columns were included in the table of run-off, showing the estimated yield per square mile of land area, exclusive of swamps or water surfaces. The present committee has omitted these deductions, but has attempted to furnish data relative to the swamps and water surface areas, which may be used as a basis of correction of the records in any manner which may be desirable. Inasmuch as the apparent water losses are the principal factor, aside from rainfall, which determines the amount of run-off, and, further, since the apparent water losses are fundamental data in the sense that they are deducible directly from the measured precipitation and run-off, a column has been added to the run-off tables containing apparent water losses. It is to be understood that "apparent water losses" are merely the difference between the measured precipitation and the measured yield, and are not necessarily the true or actual water losses for any short interval of time, since the apparent water losses include the effect of gain or loss of storage from ground water, soil, lakes, swamps, marshes, stream channels, and reservoirs. The matter of attempting to correct the apparent water losses for these effects has not been undertaken. Inasmuch as water losses are generally found to be more nearly constant over large areas than either precipitation or run-off, and the use of water losses as a factor in estimating or extending stream-flow records is apparently increasing, it was decided to include them in the tables.

Following its policy of not in general attempting to analyze the data presented, no effort has been made to estimate the mean annual precipitation on drainage basins for which the run-off is given. If, however, the mean precipitation on the drainage basin was furnished with the data from the original source, then it has been included with the data for publication.

Wherever possible, a statement of the names and locations and weights of rainfall records used in estimating the mean precipitation are given. It is to be understood, however, that the data of mean precipitation on different drainage basins are offered merely for what they are worth, and neither the committee nor the Association is directly responsible for such figures as are presented.

In a region of diversified topographic and geologic conditions, such as New England, differences in run-off or yield of adjacent drainage basins, or different parts of the same basin, especially in the case of smaller areas, may be due not to differences in rainfall or water losses at all, but to water-

shed leakage. A study of the conditions where watershed leakage is likely to occur, and an attempt to formulate rules for its detection, was undertaken by one of the members of the committee, and has been published in the JOURNAL as a contribution to the work of the committee.* Reference is made to this paper for a discussion of conditions affecting probable watershed leakage on some smaller New England drainage basins. In this connection it may be pointed out that Abbott Run, at Pawtucket, R. I., shows apparently a smaller yield in relation to precipitation than the drainage basin of the north branch of the Pawtuxet River. The geology of the Abbott Run drainage basin is complex, and the rocks are often intricately fractured and folded. It has been suggested that the apparent deficiency in yield of Abbott Run may be due to watershed leakage.

In studies of the minimum yield of drainage basins, and the amount of storage required to provide a specified constant flow, the use of daily rather than monthly records of run-off is often desirable. The committee, however, did not feel that in view of the costliness of paper and printing the presentation of the records of rainfall and run-off in a daily form is at present justified. Some of these records in daily form are given in the annual reports of the water-works departments by which the records were maintained. Such reports are commonly issued in limited editions, and as a rule are out of print shortly after their publication. References, however, to daily records, where so published, are included with the data here presented.

In many instances records of rainfall are maintained in conjunction with water-works systems where no records of run-off are kept. Inasmuch as records of rainfall throughout New England down to the end of 1913 have recently been published in the JOURNAL of the New England Water Works Association,† and since the author of this paper has offered to bring these records down to date for publication in the JOURNAL, it was deemed advisable that records of rainfall only compiled by this committee should be turned over to Mr. X. H. Goodnough, for presentation to the Association in conjunction with other records compiled by him.

In connection with this matter, a slight departure from the usual practice in the compilation of rainfall records has been made by the committee, in that, wherever available, the amounts of precipitation and the number of rainfall days in each month have been given in parallel columns. The reason for including the number of rainfall days with the precipitation is that the amount of run-off resulting from a given precipitation varies according to the manner in which the rain falls. A record of the number of rainfall days gives some indication as to whether a given amount of rain fell slowly through a prolonged period of time, or whether it fell rapidly in short heavy storms.

* "Watershed Leakage in Relation to Gravity Water Supplies." Robert E. Horton, JOURNAL N.E.W.W. ASSN., Vol. 33, No. 3, pp. 305–336.

† "Rainfall in New England," by X. H. Goodnough. JOURNAL N.E.W.W. ASSN., Vol. 39, September, 1915; pp. 237–438.

In the course of compilation of rainfall records, it was found that there were some inconsistencies, especially when results of adjacent gages were compared. A detailed study of the method and accuracy of rainfall measurements was made by one of the members of the committee as a contribution to the work of the committee, and has already been published.* The committee has not attempted to eliminate inconsistencies in rainfall records which it has compiled for publication. Illustrations of the variations in the results obtained from adjacent rain gages at certain locations in New England are, however, contained in the paper on Rainfall Measurement above referred to, and suggestions are there given as to methods of determining the probable causes of the variations in specific cases.

It is recommended that the present committee be discharged from further duties, but that in 1921 and each two years thereafter a new committee of three be appointed to compile records for the preceding two years, and that such records be published on as nearly a uniform basis as possible in the JOURNAL of the Association.

It is recommended that water-works superintendents throughout New England generally should see to it that at least one rain gage is maintained in conjunction with each water-works system. This should be a standard 8-in. Weather Bureau gage. In the winter time the depth of precipitation as snow should be measured on level ground, where no drifting occurs, preferably with the use of a snowboard. A sample of the snow should be taken and melted for the determination of the amount of precipitation.

It is recommended that where records of stream flow and precipitation are maintained in conjunction with water-works systems, daily discharges and daily amounts of precipitation should be published each year in the annual report of the superintendent of the water-works system.

In publishing rainfall records, it is desirable that each record should be accompanied by a full description of the rain gage and its location, including its size, height above ground, hour and method of making measurements, — both in the winter and summer, — surrounding topography, direction of slope of ground surface near the gage, and height and character of trees, shrubs, fences or buildings in the vicinity of the gage and their position relative thereto.

Respectfully presented,

ROBERT E. HORTON, *Chairman.*
GEO. A. CARPENTER.
SYDNEY K. CLAPP.
X. H. GOODNOUGH.
H. K. BARROWS.
Committee on Rainfall and Run-off.

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* "The Measurement of Rainfall and Snow," by Robert E. Horton. JOURNAL N.E.W.W. ASSN. Vol. 3, No. 1, pp. 14–71.

Hydrologic Description of the Drainage Basin of Hartford Supply Streams above West Hartford, Conn.

Record from — 1910 to 1917. *Years* — Eight.
Discharge obtained by — Weirs and Venturi meters.
Accuracy — Summer, good; winter, good.
Artificial regulation — Complete.
Diversions — None above point of measurement.
Source of records — Reports Hartford Board of Water Commissioners.
Drainage area, square mile — 11.92. Land, 11.22; swamp, 00; water, 0.70.
Drainage area, per cent. — 5.9% water.
Area determined from — U. S. G. S. topographic sheets, Hartford, Meriden, Middletown and Granby sheets.
Orientation — Hill-top areas extending in N-S direction.
Elevation of basin, mean — 460.
How physiographic factors were determined — Topographic maps.
Soil, kinds and location — Sandy loam.
Soil maps — None available.
General depth to ledge rock — 0 to 5 feet.
Ledge rock, kind formation and age — Igneous.
Prevailing dip — 75 ft. *Direction* — E.
Per cent. land area covered by —
Woods — 90. *Kind* — Sparse hardwood, etc.
Crops — little. *Grass* — 10. *Other cover* — 0.

Refs.— Earlier records, June, 1909, to December, 1912, from JOURNAL N.E.W.W. Assn., December, 1914, p. 508. Table shows yield land area corrected for water surface and for gain and loss of storage. See 1914 JOURNAL, p. 145.

Yield of Hartford Streams at West Hartford, Conn.
Drainage Area, 11.92 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
1910.							
Jan.	966.7	48.4	2.62	4.06	6.12	4.72	1.40
Feb.	698.4	38.6	2.09	3.24	3.81	3.44	0.37
Mar.	806.1	40.3	2.18	3.38	1.22	4.23	−3.01
Apr.	490.3	25.3	1.37	2.12	4.10	2.47	1.63
May.	194.2	9.5	0.52	0.80	2.57	1.15	1.42
June.	240.3	12.4	0.67	1.04	3.92	1.37	2.55
July	0.4	0.0	0.00	0.00	2.49	0.25	2.24
Aug.	−4.8	−0.2	−0.01	−0.02	2.52	0.18	2.34
Sept.	21.4	1.1	0.06	0.09	3.14	0.17	2.97
Oct.	−8.1	−0.4	−0.02	−0.03	0.88	0.10	0.78
Nov.	107.4	5.5	0.30	0.46	4.65	0.41	4.24
Dec.	134.2	6.7	0.36	0.56	1.66	0.69	0.97
Year.	*3 646.5*	*187.6*	*0.84*	*1.30*	*37.08*	*19.18*	*17.90*
1911.							
Jan.	254.9	12.7	0.69	1.07	2.61	1.23	1.38
Feb.	242.3	13.3	0.72	1.12	2.36	1.18	1.18
Mar.	759.4	37.9	2.06	3.18	3.75	3.82	−0.07
Apr.	744.6	38.4	2.08	3.22	2.96	3.87	−0.91
May.	80.2	4.1	0.22	0.34	1.65	0.61	1.04
June.	71.1	3.7	0.20	0.31	2.48	0.58	1.90
July	−3.9	−0.4	−0.01	−0.02	2.81	0.19	2.62
Aug.	64.2	3.2	0.17	0.27	6.06	0.30	5.76
Sept.	67.0	3.5	0.19	0.29	2.24	0.46	1.78
Oct.	960.3	47.9	2.60	4.02	9.83	4.59	5.24
Nov.	621.4	32.1	1.74	2.69	4.17	3.10	1.07
Dec.	501.6	25.0	1.36	2.10	3.19	2.49	0.70
Year.	*4 363.1*	*221.4*	*1.00*	*1.55*	*44.11*	*22.42*	*21.69*

YIELD OF HARTFORD STREAMS. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
1912.							
Jan.	108.4	5.4	0.29	0.45	1.63	0.51	1.12
Feb.	399.2	21.3	1.16	1.79	2.89	1.95	0.94
Mar.	1 113.0	55.5	3.02	4.66	6.17	5.45	0.72
Apr.	549.8	28.4	1.54	2.38	4.07	2.78	1.29
May	754.8	37.3	2.02	3.13	5.10	3.88	1.22
June	−12.9	−0.7	−0.04	−0.06	0.51	0.30	0.21
July	−17.3	−0.8	−0.05	−0.07	2.12	0.18	1.94
Aug.	−2.5	−0.1	−0.01	−0.01	3.08	0.14	2.94
Sept.	2.5	0.1	0.01	0.01	2.21	0.13	2.08
Oct.	30.6	1.5	0.08	0.13	1.92	0.23	1.69
Nov.	115.8	5.9	0.32	0.50	4.04	0.50	3.54
Dec.	347.9	17.4	0.94	1.46	4.29	1.68	2.61
Year	*3 389.3*	*171.2*	*0.78*	*1.20*	*38.03*	*17.73*	*20.30*
1913.							
Jan.	533.9	26.7	1.45	2.24	2.56	2.59	−0.03
Feb.	265.5	14.8	0.80	1.24	2.13	1.28	0.85
Mar.	955.8	47.8	2.59	4.01	5.30	4.61	0.69
Apr.	704.0	36.4	1.97	3.05	4.70	3.46	1.24
May	474.5	23.6	1.28	1.98	5.17	2.37	2.80
June	50.9	2.6	0.14	0.22	1.24	0.56	0.68
July	−40.2	−2.0	−0.11	−0.17	1.54	0.10	1.44
Aug.	−0.1	0.0	−0.00	−0.00	3.86	0.10	3.76
Sept.	31.4	1.7	0.09	0.14	3.56	0.25	3.31
Oct.	782.6	39.0	2.12	3.27	9.57	3.72	5.85
Nov.	362.2	18.7	1.01	1.57	2.45	1.86	0.59
Dec.	495.2	24.8	1.34	2.08	3.37	2.44	−0.93
Year	*4 615.7*	*234.1*	*1.06*	*1.64*	*45.45*	*23.34*	*22.11*

Month.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Month.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.
1914.				1916.			
Jan.	2.95	2.07	0.88	Jan.	1.00	2.59	−1.59
Feb.	1.99	1.26	0.73	Feb.	5.02	3.39	1.63
Mar.	3.60	4.53	−0.93	Mar.	2.21	3.39	−1.18
Apr.	3.70	3.69	0.01	Apr.	2.41	4.46	−2.05
May	2.93	2.48	0.45	May	3.30	1.87	1.43
June	2.07	0.41	1.66	June	4.52	2.42	2.10
July	4.14	0.39	3.75	July	4.42	1.05	3.37
Aug.	1.98	0.25	1.73	Aug.	4.89	0.98	3.91
Sept.	0.29	0.07	0.22	Sept.	4.45	0.48	3.97
Oct.	3.47	0.22	3.25	Oct.	1.53	0.40	1.13
Nov.	2.85	0.62	2.23	Nov.	2.98	0.86	2.12
Dec.	3.71	1.37	2.34	Dec.	2.76	1.49	1.27
Year	*33.68*	*17.36*	*16.32*	*Year*	*39.49*	*23.38*	*16.11*
1915.				1917.			
Jan.	6.65	5.16	1.49	Jan.	3.34	2.09	1.25
Feb.	4.08	4.59	−0.51	Feb.	1.71	1.05	0.66
Mar.	0.17	1.12	−0.95	Mar.	3.94	5.91	−1.97
Apr.	1.24	1.60	−0.36	Apr.	2.57	3.16	−0.59
May	2.49	0.88	1.61	May	3.73	2.51	1.22
June	4.13	0.42	3.71	June	4.51	2.09	2.42
July	4.64	0.94	3.70	July	4.13	0.98	3.15
Aug.	9.27	3.68	5.59	Aug.	4.63	0.42	4.21
Sept.	1.75	0.38	1.37	Sept.	1.20	0.25	0.95
Oct.	3.02	0.55	1.47	Oct.	7.30	1.93	5.37
Nov.	2.07	0.71	1.36	Nov.	2.36	1.36	1.00
Dec.	4.76	3.18	1.58	Dec.	1.51	1.28	0.23
Year	*44.27*	*23.21*	*21.06*	*Year*	*40.93*	*23.03*	*17.90*

HYDROLOGIC DESCRIPTION.

Stream — North Branch Pawtuxet River. *Location* — Fiskeville Dam, R. I.
Record from — 1916 to 1919. *Years* — Four.
Records obtained from — Reports Providence Board of Water Supply.
Discharge obtained by — Dam used as weir. *Gage readings taken* — Recording gage.
Accuracy — Summer, excellent; winter, excellent.
Artificial regulation — Extensive reservoirs and lakes.
Diversions — None unaccounted for.
Drainage area, square miles — 101.8. Swamp, 2.26; water, 2.14; land, 97.4.
Drainage area per cent. — 4.3% water.
Areas obtained from — Providence, Burillville, Blackstone, and Franklin, sheets. U. S. Geological Survey.
Mean slope of basin — 268 ft. per mile by contour length method.
Drainage density — 1.40 mi. per sq. mi. by lengths on U. S. maps method.
Mean elevation — 437, by contour length method. *Orientation of axis* — S. 45° E.
Soil maps — Rhode Island (Providence sheet) 1904, U. S. Soils Bureau.
Soil — 90 per cent. Gloucester stony and sandy loam.
General depth to ledge rock — 0 to 5 ft.
Ledge rock, kinds and distribution — Granetic gneiss, with complex folding and faulting.
Prevailing dip — 20° to 60°. *Direction* — Varying.
Woods, per cent. — 75. *Kind* — Sparse, mixed.
Crops, per cent. — 10. *Kind* — Mixed, potatoes, truck, etc.
Grass, per cent. — 15. *Kind* — Meadow and wild pasture. *Other culture* — 00 per cent.
No. Rainfall stations — 4 (*b*).

YIELD OF NORTH BRANCH PAWTUXET RIVER AT — ABOVE FISKEVILLE DAM.
Drainage Area, 101.8 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1916.								
Jan.....	4 519.8	225.2	1.432	2.212	1.88	1.33	2.50	—0.62
Feb. ...	6 554.0	350.0	2.220	3.434	5.88	.63	3.70	2.18
Mar....	7 064.9	352.7	2.239	3.465	2.46	1.62	3.99	—1.53
Apr.....	8 229.0	423.6	2.691	4.161	3.60	1.29	4.64	—1.04
May...	6 525.5	326.0	2.067	3.202	4.83	.76	3.69	1.14
June...	6 057.0	311.8	1.983	3.063	5.71	.60	3.42	2.29
July....	4 854.6	242.5	1.538	2.382	7.38	.37	2.74	4.64
Aug....	1 934.4	96.7	.613	0.948	1.33	.82	1.09	0.24
Sept....	738.0	38.1	.242	0.374	1.24	.34	.42	0.82
Oct.....	905.2	45.2	.287	0.444	2.61	.20	.51	2.10
Nov....	1 032.0	53.2	.338	0.523	2.34	.25	.58	1.76
Dec....	1 711.2	55.2	.542	0.838	3.30	.30	.97	2.33
Year...	*50 125.6*	*2 520.2*	*1.349*	*2.087*	*42.56*	*.67*	*28.25*	*15.31*
1917.								
Jan.....	3 382.1	168.5	1.071	1.655	3.96	.48	1.91	2.05
Feb.....	2 310.0	127.6	.810	1.253	2.18	.60	1.30	0.88
Mar....	7 588.8	379.5	2.405	3.728	4.91	.87	4.29	0.62
Apr. ...	5 391.0	277.2	1.765	2.723	2.70	1.13	3.05	—0.35
May...	4 929.0	245.6	1.562	2.413	4.15	.67	2.79	1.36
June...	3 858.0	198.4	1.263	1.949	4.54	.48	2.18	2.36
July....	1 404.3	70.0	.445	0.688	1.51	.52	.79	0.72
Aug....	1 249.3	62.4	.396	0.613	6.13	.12	.71	5.42
Sept....	1 113.0	57.3	.364	0.563	2.66	.24	.63	2.03
Oct.....	3 162.0	157.5	1.002	1.547	6.71	.27	1.79	4.92
Nov....	2 814.0	145.1	.921	1.425	.48	3.33	1.59	—1.11
Dec. ...	2 449.0	122.2	.776	1.200	3.23	.43	1.38	1.85
Year...	*39 650.5*	*2 011.3*	*1.065*	*1.646*	*43.16*	*.52*	*22.41*	*20.75*

(*b*) Weighted mean Hopkins Mills, Rocky Hill, South Scituate, and Fiskeville. Records are total yield corrected for gain or loss of storage, but not reduced to basis of net land area.

YIELD OF NORTH BRANCH PAWTUXET RIVER. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1918.								
Jan.	3 236.4	162.2	1.026	1.593	3.56	.52	1.83	1.73
Feb. . . .	7 145.6	395.3	2.507	3.883	3.73	1.09	4.04	−0.31
Mar. . . .	5 601.7	278.7	1.775	2.738	2.15	1.47	3.17	−1.02
Apr. . . .	6 012.0	310.2	1.969	3.047	4.56	.75	3.40	1.16
May . . .	3 961.8	197.6	1.255	1.941	3.12	.72	2.24	0.88
June . . .	2 187.0	112.7	0.716	1.107	4.49	.28	1.24	3.25
July	827.7	41.2	0.262	0.405	5.13	.09	0.47	4.66
Aug. . . .	1 447.7	72.3	0.459	0.710	4.14	.20	0.82	3.32
Sept. . . .	3 198.0	164.9	1.047	1.620	8.79	.21	1.81	6.98
Oct.	1 810.4	90.4	0.574	0.888	1.07	.96	1.02	0.05
Nov. . . .	2 379.0	122.7	0.779	1.205	2.60	.52	1.34	1.26
Dec. . . .	4 197.4	209.5	1.330	2.058	3.75	.63	2.37	1.38
Year . . .	*42 004.7*	*2 157.7*	*1.131*	*1.766*	*47.09*	*.50*	*23.75*	*23.34*
1919.								
Jan.	6 742.5	336.6	2.137	3.306	4.89	.78	3.81	1.08
Feb.	4 012.4	221.7	1.408	2.178	3.42	.67	2.27	1.15
Mar. . .	8 862.9	442.1	2.808	4.343	6.05	.83	5.01	1.04
Apr.	7 833.0	403.9	2.565	3.968	4.31	1.03	4.43	−0.12
May . . .	6 823.1	340.5	2.162	3.345	5.99	.65	3.86	2.13
June . . .	2 241.0	115.5	0.734	1.135	3.65	.35	1.27	2.38
July	2 390.1	119.2	0.757	1.171	5.47	.25	1.35	4.12
Aug. . . .	1 612.0	80.5	0.511	0.791	6.65	.14	0.91	5.74
Sept. . . .	5 898.0	304.1	1.931	2.987	6.07	.55	3.33	2.74
Oct.	2 575.5	127.6	0.810	1.253	2.29	.64	1.45	0.84
Nov. . . .	3 978.0	205.2	1.303	2.016	5.05	.45	2.25	2.80
Dec. . . .	4 798.8	239.5	1.521	2.353	2.58	1.05	2.71	−0.13
Year . . .	*57 767.3*	*2 936.4*	*1.553*	*2.404*	*56.42*	*.58*	*32.65*	*23.77*

HYDROLOGIC DESCRIPTION.

Stream — Abbott Run. *Location* — Pawtucket, R. I.

Record from — 1913 to 1919. *Years* — Six.

Records obtained from — Geo. A. Carpenter, Water Works, Pawtucket.

Discharge obtained by — Weir. *Gage readings taken* — Daily.

Accuracy — Summer, excellent; winter, excellent. *Artificial regulation* — Slight.

Diversions — None unaccounted for.

Drainage area, square miles — 26.94; swamp, 0.0; water, 0.73; land, 26.21.

Areas obtained from — Providence and Franklin.

Topographic sheets — U. S. Geological Survey.

Mean slope of basin — 334 ft. per mile by contour length method.

Drainage density — 1.8 mi. per sq. mi., by measuring on topographic maps.

Mean elevation — 258, by contour method. *Orientation of axis* — S. 10° E.

Soil maps — Rhode Island (Providence area) 1904, U. S. Soils Bureau.

General depth to ledge rock —

Ledge rock, kinds and distribution — Carboniferous, complex; mostly red sandstone and shale.

Prevailing dip — Steep. *Direction* — Varying.

Woods, per cent. — 33. *Kind* — Mixed.

Crops, per cent. — 33. *Kind* — Various.

Grass, per cent. — 33. *Kind* — Meadow and pasture.

One Rainfall station only, at Diamond Hill.

Records given are based on total actual yield corrected for gain or loss of storage, not reduced to basis of net land area. For earlier records see JOURNAL N. E. W. W. Assn., December, 1914, pp. 506–570.

Yield of Abbott Run Watershed.

Drainage Area, 26.94 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1913.								
Jan.....	1 557.837	77.6	1.865	2.886	3.33	1.00	3.33	0.00
Feb.....	675.682	37.1	.896	1.386	3.03	.48	1.44	1.59
Mar....	1 717.739	85.5	2.057	3.182	6.39	.56	3.54	2.85
Apr.....	1 944.708	100.1	2.406	3.723	5.06	.82	4.15	0.91
May...	712.267	35.5	.853	1.320	2.30	.66	1.52	0.78
June...	240.691	12.4	.298	0.461	1.15	.45	0.51	0.64
July....	93.571	4.6	.112	0.173	2.48	.08	0.20	2.28
Aug....	64.818	3.2	.078	0.120	3.64	.04	0.14	3.50
Sept....	102.018	5.2	.126	0.195	3.77	.06	0.22	3.55
Oct.....	397.726	19.8	.476	0.737	6.85	.12	0.85	6.00
Nov....	428.855	22.1	.531	0.821	2.66	.34	0.91	1.75
Dec....	877.363	43.6	1.051	1.625	3.88	.48	1.86	2.02
Year...	*8 813.275*	*446.7*	*.896*	*1.387*	*44.54*	*.42*	*18.67*	*25.87*
1914.								
Jan.....	897.198	44.7	1.074	1.662	4.22	.46	1.92	2.30
Feb.....	951.255	52.5	1.261	1.951	3.37	.60	2.03	1.34
Mar....	2 440.126	121.6	2.922	4.521	5.00	1.04	5.21	−0.21
Apr.....	1 864.832	96.0	2.307	3.570	5.13	.78	3.98	1.15
May...	1 344.884	67.0	1.610	2.492	2.76	1.04	2.87	−0.11
June...	248.977	12.8	0.308	0.477	0.97	.55	0.53	0.44
July....	139.299	6.9	0.167	0.258	2.82	.11	0.30	2.52
Aug....	59.005	2.9	0.071	0.109	2.67	.05	0.12	2.55
Sept....	13.378	0.7	0.017	0.026	0.41	.08	0.03	0.38
Oct.....	77.479	3.9	0.093	0.144	2.80	.06	0.17	2.63
Nov....	124.258	6.4	0.154	0.238	3.91	.07	0.27	3.64
Dec....	204.678	10.2	0.245	0.379	4.19	.11	0.44	3.75
Year...	*8 365.369*	*425.6*	*0.851*	*1.316*	*38.25*	*.47*	*17.87*	*20.38*
1915.								
Jan.....	1 828.165	91.2	2.189	3.387	7.60	.52	3.91	3.69
Feb.....	1 752.553	96.8	2.323	3.595	4.44	.84	3.74	0.70
Mar....	703.843	36.3	0.875	1.354	0.07	22.29	1.56	−1.49
Apr.....	594.971	30.7	0.736	1.139	2.32	.55	1.27	1.05
May...	345.239	17.2	0.413	0.640	1.72	.44	0.74	0.98
June...	206.404	10.6	0.255	0.395	3.22	.14	0.44	2.78
July....	1 277.834	63.8	1.530	2.367	8.81	.31	2.73	6.08
Aug....	605.459	30.1	0.725	1.122	5.05	.26	1.29	3.76
Sept....	197.077	10.1	0.244	0.377	0.52	.81	0.42	0.10
Oct.....	181.594	9.0	0.217	0.336	2.87	.14	0.39	2.48
Nov....	216.019	11.1	0.267	0.414	2.51	.19	0.46	2.05
Dec....	667.920	33.4	0.800	1.237	5.39	.27	1.43	3.96
Year...	*8 604.078*	*440.3*	*0.875*	*1.354*	*44.52*	*.41*	*18.38*	*26.14*
1916....								
Jan.....	874.136	43.6	1.047	1.619	2.19	.85	1.87	0.32
Feb.....	1 185.469	63.2	1.517	2.348	6.03	.42	2.53	3.50
Mar....	1 547.217	77.2	1.853	2.866	3.39	.98	3.31	0.08
Apr.....	2 010.951	103.6	2.488	3.850	4.17	1.03	4.29	−0.12
May...	1 516.442	75.6	1.816	2.809	4.49	.72	3.24	1.25
June...	1 321.940	68.1	1.636	2.531	5.98	.47	2.82	3.16
July....	1 171.012	58.4	1.402	2.170	8.25	.30	2.50	5.75
Aug....	453.731	22.6	0.543	0.840	1.84	.53	0.97	0.87
Sept....	140.126	7.2	0.173	0.268	1.33	.20	0.30	1.03
Oct.....	214.187	10.7	0.256	0.397	2.47	.19	0.46	2.01
Nov....	150.203	7.7	0.186	0.288	2.66	.12	0.32	2.34
Dec....	266.733	13.3	0.319	0.494	3.35	.17	0.57	2.78
Year...	*10 852.147*	*551.2*	*1.104*	*1.703*	*46.15*	*.50*	*23.18*	*22.97*

YIELD OF ABBOTT RUN WATERSHED. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1917.								
Jan.....	615.067	30.7	0.736	1.140	3.37	.39	1.31	2.06
Feb.....	522.247	28.8	0.692	1.071	2.87	.39	1.12	1.75
Mar....	1 757.865	87.7	2.105	3.257	5.27	.71	3.76	1.51
Apr.....	1 505.640	77.5	1.863	2.883	3.09	1.04	3.22	−0.13
May...	1 290.572	64.3	1.545	2.391	4.66	.59	2.76	1.90
June...	1 110.212	57.3	1.374	2.125	4.91	.48	2.37	2.54
July....	319.156	15.9	0.382	0.591	0.95	.72	0.68	0.27
Aug....	403.744	20.1	0.484	0.748	8.15	.11	0.86	7.29
Sept....	198.990	10.2	0.246	0.381	2.46	.17	0.42	2.04
Oct.....	562.375	28.0	0.673	1.042	6.77	.18	1.20	5.57
Nov....	684.191	35.2	0.846	1.310	0.43	3.40	1.46	−1.03
Dec. ...	570.681	28.5	0.683	1.057	3.42	.36	1.22	2.20
Year...	*9 540.735*	*484.2*	*0.970*	*1.501*	*46.35*	*.44*	*20.38*	*25.97*
1918.								
Jan.....	800.456	39.8	0.985	1.483	3.94	.44	1.71	2.23
Feb.....	1 513.658	83.7	2.007	3.105	2.81	1.15	3.23	−0.42
Mar....	1 415.786	70.5	1.695	2.623	2.66	1.14	3.02	−0.36
Apr.....	1 345.935	69.4	1.665	2.577	4.09	.70	2.87	1.22
May...	863.851	43.0	1.034	1.600	2.49	.75	1.85	0.64
June...	316.052	16.3	0.391	0.605	3.48	.20	0.68	2.80
July....	111.516	5.6	0.134	0.207	2.63	.09	0.24	2.39
Aug....	76.641	3.8	0.092	0.142	1.93	.09	0.16	1.77
Sept....	562.147	29.1	0.696	1.076	9.20	.13	1.20	8.00
Oct.....	367.785	18.3	0.440	0.681	0.60	1.32	0.79	−0.19
Nov....	365.710	18.8	0.452	0.700	2.29	.34	0.78	1.51
Dec. ...	861.278	43.0	1.031	1.596	3.88	.48	1.84	2.04
Year...	*8 600.815*	*441.3*	*0.875*	*1.353*	*40.00*	*.46*	*18.37*	*21.63*
1919.								
Jan.....	1 492.447	74.5	1.787	2.765	4.81	.66	3.19	1.62
Feb.....	1 039.704	57.3	1.378	2.133	3.43	.65	2.22	1.21
Mar....	2 131.010	106.2	2.552	3.948	5.53	.82	4.55	0.98
Apr.....	1 560.224	80.4	1.930	2.987	3.28	1.02	3.33	−0.05
May...	1 343.004	67.0	1.608	2.488	5.25	.55	2.87	2.38
June...	419.062	21.6	0.519	0.802	1.95	.47	0.90	1.05
July....	399.119	19.9	0.478	0.739	5.99	.14	0.85	5.14
Aug....	248.055	12.4	0.297	0.460	4.64	.12	0.53	4.11
Sept....	1 028.761	53.0	1.273	1.969	5.36	.41	2.20	3.16
Oct.....	519.810	25.9	0.622	0.963	2.32	.48	1.11	1.21
Nov....	994.418	51.1	1.231	1.904	3.73	.57	2.12	1.61
Dec. ...	1 122.803	54.0	1.344	2.008	2.24	1.08	2.40	−0.16
Year...	*12 298.417*	*623.3*	*1.251*	*1.935*	*48.53*	*.54*	*26.27*	*22.26*

Hydrologic Description.

Stream — Stony Brook.

Location — Cambridge, Mass.

Record from — 1909 to 1919. *Years* — Twelve.

Records obtained from — L. M. Hastings, city engineer.

Discharge obtained by — Reservoir and pumpage records.

Gage readings taken — Daily.

Accuracy — Summer, good; winter, good.

Diversions — None unaccounted for.

Drainage area, square miles — 23.57. Swamp, 2.00; water, 1.00; land, 20.57.

Areas obtained from — Boston and Framingham topographic sheets, U. S. Geological Survey.

Mean slope of basin — Not determined.

Drainage density — Not determined.

Mean elevation — Not determined.

Orientation of axis — S. 50° E.

Soil maps — Not available

Soil — Sandy loam.

General depth to ledge rock — Unknown.

Ledge rock, kinds and distribution — Complex, mainly igneous gneisses and schists.

Prevailing dip — Unknown. *Direction* — Unknown

Woods, per cent. — 50. *Kind* — Sparse, mixed.

Crops, per cent. — 20–30. *Grass, per cent.* — 20–30.

For earlier records see Journal N. E. W. W. Assn., December, 1914, pp. 486–487.

Figures here given are actual yield corrected for storage but not reduced to basis of net land area.

Yield of Stony Brook Watershed.
Drainage Area, 23.57 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
			M.G.D.	C.F.S.				
1912.								
Jan.....	572.0	28.6	0.783	1.211	2.65	.39	1.04	1.61
Feb.....	884.3	47.2	1.294	1.996	2.43	.86	2.08	0.35
Mar....	1 825.9	91.3	2.499	3.867	5.93	.75	4.46	1.47
Apr.....	1 440.3	74.5	2.037	3.156	4.01	.76	3.03	0.98
May . . .	901.9	44.8	1.234	1.903	5.14	.43	2.20	2.94
June . . .	151.2	7.8	0.214	0.331	0.24	1.56	.37	−0.13
July....	120.9	6.0	0.165	0.255	5.06	.06	.30	4.76
Aug....	66.2	3.3	0.091	0.139	2.40	.07	.16	2.24
Sept....	18.4	0.9	0.026	0.040	1.94	.03	.05	1.89
Oct.....	107.3	5.3	0.147	0.227	2.76	.10	.26	2.50
Nov....	219.6	11.4	0.311	0.481	3.01	.18	.54	2.47
Dec. ...	424.7	21.2	0.581	0.899	4.88	.21	1.04	3.84
Year . . .	*6 732.7*	*342.3*	*0.782*	*1.209*	*40.45*	*.38*	*15.53*	*24.92*
1913.								
Jan.....	820.0	40.8	1.122	1.733	2.82	.71	2.00	0.82
Feb.....	493.4	27.3	0.748	1.157	3.17	.38	1.20	1.97
Mar....	1 322.5	66.0	1.809	2.800	5.30	.61	3.23	2.07
Apr.....	1 447.0	74.8	2.046	3.171	4.28	.83	3.53	0.75
May . . .	658.1	33.9	0.933	1.443	3.99	.42	1.67	2.32
June . . .	148.0	7.6	0.209	0.323	1.17	.31	0.36	0.81
July....	36.0	2.5	0.068	0.105	3.15	.03	0.10	3.05
Aug....	168.0	8.4	0.229	0.354	3.98	.11	0.41	3.57
Sept....	106.0	5.5	0.149	0.231	3.34	.08	0.26	3.08
Oct.....	456.0	22.8	0.624	0.965	5.90	.06	0.36	5.54
Nov....	355.0	18.3	0.502	0.777	2.16	.40	0.87	1.29
Dec. ...	604.5	30.2	0.827	1.279	2.85	.52	1.48	1.37
Year . . .	*6 614.5*	*338.1*	*0.772*	*1.195*	*42.11*	*.37*	*15.47*	*26.64*

Yield of Stony Brook Watershed. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1914.								
Jan.	424.7	21.2	0.581	0.899	3.23	.32	1.04	2.19
Feb.	591.9	32.7	0.896	1.386	3.07	.47	1.45	1.62
Mar. . . .	2 190.6	109.2	2.988	4.626	4.82	1.11	5.35	−0.53
Apr.	1 841.1	94.9	2.604	4.022	5.25	.86	4.50	0.75
May . . .	1 314.4	65.8	1.799	2.785	2.60	1.24	3.21	−0.61
June . . .	93.0	4.8	0.131	0.203	1.94	.12	0.23	1.71
July. . . .	97.0	4.9	0.133	0.206	2.46	.10	0.24	2.22
Aug. . . .	79.0	3.9	0.108	0.167	3.92	.05	0.20	3.72
Sept. . . .	−15.0	−0.7	−0.021	−0.032	0.24	−.17	− 0.04	0.28
Oct.	15.0	0.7	0.021	0.032	1.69	.03	0.04	1.65
Nov. . . .	77.0	4.0	0.109	0.169	2.57	.08	0.19	2.38
Dec. . . .	171.0	8.5	0.234	0.362	3.39	.13	0.42	2.97
Year . . .	*6 879.7*	*349.9*	*0.815*	*1.235*	*35.18*	*.48*	*16.83*	*18.35*
1915.								
Jan.	892.8	44.3	1.222	1.889	5.89	.37	2.18	3.71
Feb.	1 128.4	62.3	1.709	2.645	3.65	.76	2.76	0.89
Mar. . . .	408.6	20.4	0.559	0.865	. . . .	. . . .	1.00	−1.00
Apr.	425.1	21.9	0.601	0.930	2.31	.45	1.04	1.27
May . . .	256.8	12.6	0.351	0.543	2.38	.27	0.63	1.75
June . . .	216.0	7.0	0.192	0.297	1.66	.20	0.33	1.33
July. . . .	742.5	37.2	1.016	1.578	9.95	.18	1.81	8.14
Aug. . . .	820.4	41.7	1.123	1.766	6.22	.32	2.00	4.22
Sept. . . .	96.0	5.0	0.136	0.210	0.94	.25	0.23	0.71
Oct.	171.0	8.5	0.234	0.362	2.98	.14	0.42	2.56
Nov. . . .	552.8	28.6	0.782	1.210	2.68	.25	0.66	2.02
Dec. . . .	576.0	28.8	0.788	1.219	5.13	.28	1.41	3.72
Year . . .	*6 286.4*	*318.5*	*0.726*	*1.126*	*43.79*	*.33*	*14.47*	*29.32*
1916.								
Jan.	179.8	9.0	0.246	0.381	1.35	.33	0.44	0.91
Feb.	919.9	48.9	1.336	2.073	5.35	.42	2.23	3.12
Mar. . . .	1 383.4	68.9	1.893	2.924	4.13	.82	3.37	0.76
Apr.	1 955.2	100.8	2.765	4.270	4.39	1.09	4.77	−0.38
May . . .	1 147.1	57.3	1.570	2.429	3.19	.88	2.80	0.39
June . . .	1 022.1	52.6	1.445	2.228	5.87	.43	2.50	3.37
July. . . .	368.9	18.4	0.505	0.781	3.53	.26	0.90	2.63
Aug. . . .	90.5	4.5	0.124	0.192	2.14	.10	0.22	1.92
Sept. . . .	1 300.0	67.3	1.838	2.847	1.45	.23	0.32	1.13
Oct.	36.0	1.8	0.049	0.076	1.19	.08	0.09	1.10
Nov. . . .	79.0	4.1	0.112	0.173	1.70	.12	0.19	1.51
Dec. . . .	195.0	9.7	0.267	0.413	3.79	.13	0.48	3.31
Year . . .	*8 676.9*	*443.3*	*1.013*	*1.566*	*38.08*	*.48*	*18.31*	*19.77*
1917.								
Jan.	354.0	17.7	0.484	0.749	3.02	.29	0.86	2.16
Feb.	785.1	43.4	1.189	1.841	2.57	.75	1.91	0.66
Mar. . . .	1 307.9	65.4	1.790	2.769	4.34	.74	3.19	1.15
Apr.	963.3	49.6	1.362	2.104	2.67	.88	2.35	0.32
May . . .	1 068.3	53.3	1.462	2.259	4.82	.54	2.61	2.21
June . . .	732.0	38.0	1.035	1.609	4.11	.43	1.78	2.33
July. . . .	106.3	5.3	0.146	0.226	1.02	.26	0.26	0.76
Aug. . . .	159.0	8.0	0.218	0.337	4.11	.10	0.39	3.72
Sept. . . .	36.0	1.9	0.051	0.079	1.97	.05	0.09	1.88
Oct.	326.0	16.3	0.446	0.690	5.61	.14	0.80	4.81
Nov. . . .	188.0	9.8	0.270	0.416	0.82	.57	0.46	0.36
Dec. . . .	195.0	9.7	0.267	0.413	2.84	.17	0.48	2.36
Year . . .	*6 220.9*	*318.4*	*0.727*	*1.124*	*37.90*	*.40*	*15.18*	*22.72*

Yield of Stony Brook Watershed. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1918.								
Jan.....	168.0	8.4	0.229	0.354	3.12	.13	0.41	2.71
Feb.....	1 061.4	61.3	1.683	2.599	2.34	1.16	2.71	−0.37
Mar....	1 248.7	62.5	1.709	2.645	3.35	.91	3.05	0.30
Apr.....	915.6	47.4	1.295	2.011	2.94	.76	2.24	0.70
May...	431.2	21.5	0.590	0.913	2.34	.45	1.05	1.29
June...	171.0	8.8	0.242	0.374	3.07	.14	0.42	2.65
July....	87.1	4.3	0.119	0.184	3.54	.06	0.21	3.33
Aug....	−28.0	−1.4	−0.038	−0.059	1.78	.04	0.07	1.71
Sept....	462.0	23.8	0.653	1.010	8.82	.13	1.11	7.71
Oct.....	220.1	11.0	0.301	0.466	0.93	.59	0.54	0.39
Nov....	285.0	14.7	0.403	0.623	2.40	.29	0.70	1.70
Dec. ...	602.3	19.4	0.824	1.275	3.36	.44	1.47	1.89
Year...	*5 624.4*	*281.7*	*0.668*	*1.033*	*37.99*	*.37*	*13.98*	*24.01*
1919.								
Jan.....	873.1	43.4	1.186	1.841	4.00	.53	2.13	1.87
Feb.....	849.0	47.2	1.286	1.996	3.21	.65	2.07	1.14
Mar....	1 478.1	73.6	3.023	3.125	4.54	.80	3.61	0.93
Apr.....	967.8	50.0	1.368	2.119	2.72	.87	2.35	0.37
May...	1 054.0	52.6	1.442	2.228	5.81	.44	2.57	3.24
June...	24.6	1.3	0.035	0.054	1.39	.43	0.60	0.79
July....	264.0	13.2	0.361	0.558	5.75	.11	0.64	5.11
Aug....	222.0	11.1	0.304	0.470	5.49	.10	0.54	4.95
Sept....	632.9	32.6	0.895	1.384	7.42	.21	1.57	5.85
Oct.....	212.3	10.6	0.291	0.450	2.10	.25	0.52	1.58
Nov....	875.5	45.3	1.238	1.918	5.38	.40	2.14	3 24
Dec. ...	896.8	44.8	1.227	1.903	1.73	1.27	2.19	−0.46
Year...	*8 350.1*	*425.7*	*0.971*	*1.504*	*49.54*	*.42*	*20.93*	*28.61*

Hydrologic Description.

Springfield Water Works. *Stream* — Westfield Little River.

Location — Near Westfield, Mass.

Record from — 1912 to 1919. *Years* — Eight

Records obtained from — E. E. Lochridge, chief engineer.

Discharge obtained by — Weir. *Gage readings taken* — Daily.

Accuracy — Summer, excellent; winter, excellent.

Artificial regulation — None. *Diversions* — None.

Drainage area, square miles — 48.50. Swamp; water, 0.69; land, 47.81.

Areas obtained from — Granville and Standisfield. Topographic sheets — U. S. Geological Survey maps.

Mean slope of basin — 535 ft. per mile by contour method.

Drainage density — Not determined.

Mean elevation — Not determined.

Orientation of axis — S. 45° E.

Soil maps — None available.

General depth to ledge rock — 0 to 5 ft.

Ledge rock, kinds and distribution — Granetic.

Prevailing dip — Not determined. *Direction* — Not determined.

Woods, per cent. — 75. *Kind* — Mixed.

Crops, per cent. — 5. *Grass, per cent.* — 20.

Figures given show actual yield corrected for gain or loss of storage, but not reduced to basis of net land area. For earlier records see Water Supply Papers, U. S. Geological Survey, for North Atlantic Slope Drainage basins. Also Journal N. E. W. W. Assn., December, 1914, pp. 500–502.

Yield of Westfield Little River, near Westfield.

Drainage Area, 48.5 Sq. Mi.

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1912.								
Jan.....	1 511	76.1	1.01	1.57	2.56	.70	1.79	0.77
Feb.....	2 553	135.8	1.81	2.80	3.04	1.00	3.03	0.01
Mar....	7 049	352.1	4.69	7.26	5.88	1.42	8.36	−2.48
Apr.....	4 837	249.8	3.32	5.15	5.81	.99	5.74	0.07
May...	3 033	151.8	2.02	3.13	4.91	.73	3.60	1.31
June...	835	42.7	0.57	0.88	0.54	1.84	0.99	−0.45
July....	126	5.8	0.08	0.12	2.55	.06	0.15	2.40
Aug....	231	11.1	0.15	0.23	3.83	.07	0.27	3.56
Sept....	334	17.5	0.23	0.36	3.79	.11	0.40	3.39
Oct.....	744	36.9	0.49	0.76	5.57	.16	0.88	4.69
Nov....	1 837	94.6	1.26	1.95	4.60	.47	2.18	2.42
Dec. ...	2 297	114.5	1.52	2.36	4.81	.57	2.72	2.09
Year...	*25 387*	*1 288.7*	*1.43*	*2.22*	*47.89*	*.63*	*30.11*	*17.78*
1913.								
Jan.....	3 342	167.8	2.23	3.46	4.21	.94	3.96	0.25
Feb.....	897	49.5	0.66	1.02	2.33	.46	1.06	1.27
Mar....	4 171	208.1	2.77	4.29	6.47	.77	4.95	1.52
Apr.....	2 553	131.4	1.75	2.71	3.90	.78	3.03	0.87
May...	1 794	90.2	1.20	1.86	4.97	.43	2.13	2.84
June...	404	20.8	0.28	0.43	1.00	.48	0.48	0.52
July....	48	2.4	0.03	0.05	1.51	.04	0.06	1.45
Aug....	71	3.9	0.05	0.08	2.56	.03	0.08	2.48
Sept....	158	8.2	0.11	0.17	3.34	.06	0.19	3.15
Oct.....	2 001	99.9	1.33	2.06	8.45	.28	2.37	6.08
Nov....	2 223	114.5	1.52	2.36	4.80	.55	2.64	2.16
Dec. ...	1 574	79.1	1.05	1.63	2.94	.64	1.87	1.07
Year...	*19 236*	*975.8*	*1.08*	*1.67*	*46.48*	*.49*	*22.82*	*23.66*
1914.								
Jan.....	1 142	57.2	0.76	1.18	2.32	.59	1.36	0.96
Feb.....	1 190	66.0	0.88	1.36	4.14	.34	1.41	2.73
Mar....	4 644	232.3	3.09	4.79	6.60	.84	5.51	1.09
Apr.....	6 056	312.8	4.16	6.45	6.13	1.17	7.19	−1.06
May...	2 200	109.6	1.46	2.26	2.44	1.07	2.61	−0.17
June...	253	13.6	0.18	0.28	2.33	.13	0.30	2.03
July....	265	13.6	0.18	0.28	3.61	.09	0.31	3.30
Aug....	108	5.3	0.07	0.11	2.27	.06	0.13	2.14
Sept....	46	2.4	0.03	0.05	0.19	.26	0.05	0.14
Oct.....	104	5.3	0.07	0.11	2.31	.06	0.12	2.19
Nov....	808	41.2	0.55	0.85	3.75	.26	0.96	2.79
Dec. ...	347	17.5	0.23	0.36	4.60	.09	0.41	4.19
Year...	*17 163*	*876.8*	*0.97*	*1.50*	*40.69*	*.49*	*20.36*	*20.33*
1915.								
Jan.....	3 552	177.5	2.36	3.66	7.43	.57	4.21	3.22
Feb.....	4 530	250.7	3.34	5.17	6.24	.86	5.37	0.87
Mar....	1 027	50.9	0.68	1.05	0.35	3.49	1.22	−0.87
Apr.....	2 706	139.7	1.86	2.88	3.94	.81	3.21	0.73
May...	1 626	81.0	1.08	1.67	2.36	.82	1.93	0.43
June...	678	34.9	0.47	0.72	4.70	.17	0.80	3.90
July....	2 232	111.1	1.48	2.29	7.18	.37	2.65	4.53
Aug....	2 090	104.3	1.39	2.15	8.39	.30	2.48	5.91
Sept....	395	19.8	0.27	0.41	2.55	.19	0.47	2.08
Oct.....	569	28.6	0.38	0.59	2.62	.26	0.67	1.95
Nov....	831	42.7	0.57	0.88	3.60	.28	0.99	2.61
Dec. ...	2 791	139.7	1.86	2.88	8.58	.39	3.31	5.27
Year...	*23 027*	*1 180.9*	*1.30*	*2.02*	*57.94*	*.47*	*27.31*	*30.63*

Yield of Westfield Little River. — *Continued.*

Month.	Total Mill. Gal.	Mean C.F.S.	Per Sq. Mile. M.G.D.	Per Sq. Mile. C.F.S.	Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
1916.								
Jan.	2 662	132.9	1.77	2.74	2.40	1.32	3.16	−0.76
Feb.	2 345	124.6	1.66	2.57	6.79	.41	2.78	4.01
Mar.	1 779	88.8	1.18	1.83	5.45	.39	2.11	3.34
Apr.	6 936	358.4	4.77	7.39	4.19	1.96	8.22	−4.03
May	1 861	93.1	1.24	1.92	3.64	.61	2.21	1.43
June	1 989	102.3	1.36	2.11	5.85	.40	2.36	3.49
July	1 474	73.7	0.98	1.52	6.26	.28	1.75	4.51
Aug.	398	20.4	0.27	0.42	2.65	.18	0.47	2.18
Sept.	710	36.9	0.49	0.76	6.70	.13	0.84	5.86
Oct.	532	27.2	0.36	0.56	1.56	.41	0.63	0.93
Nov.	1 004	51.9	0.69	1.07	4.44	.27	1.19	3.25
Dec.	1 338	66.9	0.89	1.38	3.70	.43	1.59	2.11
Year	*23 028*	*1 177.1*	*1.30*	*2.02*	*53.63*	*.54*	*27.31*	*26.32*
1917.								
Jan.	1 678	84.4	1.12	1.74	3.18	.63	1.99	1.19
Feb.	896	49.5	0.66	1.02	4.12	.26	1.06	3.06
Mar.	2 848	142.1	1.89	2.93	4.75	.71	3.38	1.37
Apr.	5 010	258.5	3.44	5.33	3.20	1.86	5.95	−2.75
May	2 937	146.5	1.95	3.02	4.20	.83	3.48	0.72
June	1 925	99.4	1.32	2.05	5.15	.44	2.28	2.87
July	424	20.9	0.28	0.43	2.35	.21	0.50	1.85
Aug.	259	12.6	0.17	0.26	3.73	.09	0.31	3.42
Sept.	210	10.7	0.14	0.22	1.00	.25	0.25	0.75
Oct.	1 116	55.8	0.74	1.15	8.65	.15	1.32	7.33
Nov.	690	35.4	0.47	0.73	0.90	.92	0.82	0.08
Dec.	484	24.2	0.32	0.50	4.90	.12	0.58	4.32
Year	*18 477*	*940.0*	*1.04*	*1.61*	*46.13*	*.48*	*21.92*	*24.21*
1918.								
Jan.	633	33.0	0.44	0.68	3.40	.23	0.79	2.61
Feb.	2 002	110.6	1.47	2.28	3.82	.62	2.37	1.45
Mar.	5 412	270.6	3.60	5.58	2.83	2.27	6.42	−3.59
Apr.	3 021	155.7	2.07	3.21	3.51	1.02	3.58	−0.07
May	1 158	57.7	0.77	1.19	2.02	.68	1.37	0.65
June	597	31.0	0.41	0.64	2.35	.31	0.71	1.64
July	176	9.2	0.12	0.19	2.65	.08	0.21	2.44
Aug.	227	11.2	0.15	0.23	4.06	.07	0.27	3.79
Sept.	618	31.5	0.42	0.65	6.83	.11	0.73	6.10
Oct.	368	17.9	0.24	0.37	1.47	.30	0.44	1.03
Nov.	796	41.2	0.55	0.85	2.92	.32	0.94	1.98
Dec.	1 826	91.2	1.21	1.88	3.83	.57	2.17	1.66
Year	*16 864*	*860.8*	*0.95*	*1.48*	*39.69*	*.50*	*20.00*	*19.69*
1919.								
Jan.	1 403	70.3	0.93	1.45	2.52	.66	1.67	0.85
Feb.	593	33.0	0.44	0.68	4.06	.17	0.70	3.36
Mar.	4 656	233.3	3.10	4.81	5.61	.99	5.53	0.08
Apr.	4 109	212.4	2.82	4.38	3.67	1.33	4.87	−1.20
May	4 453	222.6	2.96	4.59	8.76	.60	5.28	3.48
June	425	21.8	0.29	0.45	1.04	.49	0.50	0.54
July	383	19.4	0.25	0.40	5.00	.09	0.45	4.55
Aug.	306	15.5	0.20	0.32	3.80	.09	0.36	3.44
Sept.	584	30.1	0.40	0.62	6.11	.11	0.69	5.42
Oct.	460	23.3	0.31	0.48	2.52	.22	0.55	1.97
Nov.	2 273	117.3	1.56	2.42	7.06	.38	2.70	4.36
Dec.	1 854	92.6	1.23	1.91	2.70	.82	2.20	0.50
Year	*21 499*	*1 091.6*	*1.21*	*1.88*	*52.85*	*.48*	*25.50*	*27.35*

HYDROLOGIC DESCRIPTION.

Stream — Manhan River. *Location* — Southampton, Mass.
Records from — 1897 to 1919. *Years* — Twenty-three.
Records obtained from — P. J. Lucey, engineer, Holyoke Water Department.
Discharge obtained by — Weir. *Gage readings taken* — Daily.
Accuracy — Summer, excellent; winter, excellent.
Artificial regulation — None. *Diversions* — None unaccounted for.
Drainage area, square miles — 13. Swamp, 0.33; water, little; land, 13.
Areas obtained from — Springfield, Granville, and Chesterfield. Topographic Sheets, U. S. Geological Survey.
Mean slope of basin — 552 ft. per mile by contour method.
Drainage density — Not determined.
Mean elevation — 950 ft. by contour method.
Orientation of axis — S. 20° E.
Soil maps — Conn. Valley sheet (1903), U. S. Soils Bureau.
Soil — Sandy loam.
General depth to ledge rock — Unknown.
Ledge rock, kinds and distribution — Granetic.
Prevailing dip — Unknown. *Direction* — Unknown.
Woods, per cent. — 65. *Kind* — Mixed, sparse.
Crops, per cent. — 10. *Grass, per cent.* — 25.
Number rainfall stations — 1.

Records given show actual yield corrected for gain and loss of storage but not reduced to a basis of net land area. See also JOURNAL N. E. W. W. Assn., December, 1914, pp. 486–488, and December, 1920, pp. 323–356.

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER AT SOUTHAMPTON, MASS.
Drainage Area, 13 Sq. Mi.

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1897.						
Jan.	0.645	0.998	4.29	.268	1.150	3.140
Feb.	1.071	1.655	2.89	.596	1.723	1.167
Mar.	2.439	3.775	3.27	1.331	4.352	−1.082
Apr.	2.087	3.233	2.41	1.497	3.608	−1.198
May	1.168	1.810	4.05	.515	2.087	1.963
June	1.629	2.521	7.16	.393	2.814	4.346
July	4.560	7.054	13.96	.583	8.132	5.828
Aug.	1.911	2.955	6.32	.539	3.407	2.913
Sept.	0.583	0.902	1.235	.815	1.007	0.228
Oct.	0.317	0.490	1.25	.452	0.565	0.685
Nov.	1.122	1.732	6.01	.321	1.933	4.077
Dec.	2.301	3.558	6.57	.624	4.101	2.469
Year	*1.661*	*2.569*	*59.415*	*.587*	*34.879*	*24.536*
1898.						
Jan.	1.378	2.134	5.765	.427	2.461	3.304
Feb.	1.117	1.732	4.47	.404	1.804	2.666
Mar.	3.777	5.847	2.49	2.707	6.741	−4.251
Apr.	2.293	3.542	4.195	.942	3.953	0.242
May	2.443	3.774	6.16	.706	4.351	1.809
June	1.236	1.918	4.165	.513	2.139	2.026
July	0.345	0.534	3.955	.156	0.616	3.339
Aug.	0.670	1.036	7.275	.164	1.194	6.081
Sept.	0.298	0.461	3.35	.153	0.514	2.836
Oct.	1.269	1.964	7.405	.306	2.265	5.140
Nov.	1.912	2.955	5.92	.557	3.296	2.624
Dec.	1.519	2.351	3.73	.727	2.711	1.019
Year	*1.526*	*2.360*	*58.88*	*.544*	*32.045*	*26.835*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1899.						
Jan.	1.470	2.274	3.04	.861	2.62	0.42
Feb.	0.723	1.118	3.36	.346	1.16	2.20
Mar.	1.633	2.526	6.87	.424	2.91	3.96
Apr.	4.926	7.622	1.92	4.429	8.50	−6.58
May	0.826	1.278	1.31	1.124	1.47	−0.16
June	0.248	0.383	2.43	.175	0.43	2.00
July	0.364	0.563	5.07	.128	0.65	4.42
Aug.	0.128	0.198	1.94	.117	0.23	1.71
Sept.	0.298	0.461	5.01	.102	0.51	4.50
Oct.	0.198	0.303	1.31	.268	0.35	0.96
Nov.	0.434	0.671	3.16	.237	0.75	2.41
Dec.	0.451	0.697	2.86	.281	0.80	2.06
Year	*0.975*	*1.508*	*38.28*	*.532*	*20.38*	*17.90*
1900.						
Jan.	0.472	0.733	3.59	.234	0.84	2.75
Feb.	4.150	6.421	10.28	.650	6.69	3.59
Mar.	2.801	4.344	5.54	.901	4.99	0.55
Apr.	1.985	3.071	1.88	1.817	3.42	−1.54
May	1.521	2.353	4.44	.611	2.71	1.73
June	0.374	0.578	1.78	.362	0.64	1.14
July	0.149	0.235	2.49	.106	0.16	2.33
Aug.	0.170	0.263	3.91	.077	0.30	3.61
Sept.	0.079	0.122	2.11	.064	0.13	1.98
Oct.	0.183	0.283	3.42	.095	0.32	3.10
Nov.	0.993	1.536	4.31	.397	1.71	2.60
Dec.	0.951	1.471	3.27	.518	1.70	1.57
Year	*1.152*	*1.784*	*47.02*	*.502*	*23.61*	*23.41*
1901.						
Jan.	0.304	0.470	2.11	.257	0.542	1.568
Feb.	0.197	0.305	0.78	.406	0.317	0.463
Mar.	2.214	3.419	6.29	.630	3.941	2.349
Apr.	6.517	10.086	10.98	1.025	11.252	−0.272
May	3.969	6.141	9.87	.717	7.080	2.790
June	1.016	1.577	1.96	.898	1.760	0.200
July	0.289	0.447	2.59	.199	0.515	2.075
Aug.	0.626	0.968	6.15	.181	1.116	5.034
Sept.	0.861	1.332	4.76	.312	1.486	3.274
Oct.	0.767	1.186	4.77	.287	1.369	3.401
Nov.	0.525	0.812	1.54	.588	0.906	0.634
Dec.	2.643	4.084	4.79	.983	4.709	0.081
Year	*1.667*	*2.569*	*56.59*	*.618*	*34.993*	*21.597*
1902.						
Jan.	2.342	3.620	3.32	1.257	4.173	−0.853
Feb.	1.296	2.011	4.66	4.99	2.094	2.566
Mar.	4.290	6.637	6.38	1.199	7.651	−1.271
Apr.	2.325	3.635	4.45	.911	4.055	0.395
May	0.995	1.539	2.08	.853	1.775	0.305
June	0.396	0.613	2.85	.240	0.684	2.166
July	0.558	0.863	5.75	.173	0.994	4.756
Aug.	0.502	0.776	4.63	.196	0.894	3.736
Sept.	0.761	1.177	5.34	.246	1.313	4.027
Oct.	1.652	2.552	6.99	.421	2.943	4.047
Nov.	0.914	1.414	1.62	.974	1.577	0.043
Dec.	1.815	2.800	7.46	.433	3.228	4.232
Year	*1.493*	*2.303*	*55.53*	*.565*	*31.381*	*24.149*

Yield of Southwest Branch of Manhan River. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1903.						
Jan.	1.472	2.274	1.88	1.394	2.622	−0.742
Feb.	2.077	3.218	5.30	0.632	3.351	1.949
Mar.	4.055	6.280	5.57	1.300	7.240	−1.670
Apr.	2.720	4.208	3.63	1.293	4.694	−1.064
May	0.549	0.849	0.89	1.099	0.978	−0.088
June	2.719	4.208	14.33	0.328	4.694	9.636
July	1.139	1.764	3.80	0.535	2.034	1.766
Aug.	1.472	2.274	7.815	0.336	2.622	5.193
Sept.	0.648	1.002	2.385	0.468	1.118	1.267
Oct.	1.358	2.103	3.915	0.619	2.425	1.490
Nov.	0.965	1.493	1.70	0.977	1.664	0.036
Dec.	1.562	2.412	6.28	0.443	2.780	3.500
Year	*1.728*	*2.674*	*57.495*	*.625*	*36.222*	*21.273*
1904.						
Jan.	0.707	1.094	3.60	0.349	1.261	2.339
Feb.	0.662	1.024	2.61	0.423	1.104	1.506
Mar.	2.650	4.099	4.43	1.067	4.726	−0.296
Apr.	4.751	7.348	6.87	1.193	8.197	−1.327
May	1.741	2.692	4.22	0.735	3.104	1.116
June	2.119	3.280	6.65	0.550	3.659	2.991
July	0.642	0.993	3.01	0.380	1.144	1.866
Aug.	0.503	0.778	5.07	0.177	0.896	4.174
Sept.	0.848	1.312	4.73	0.309	1.464	3.266
Oct.	0.936	1.448	3.56	0.468	1.668	1.892
Nov.	0.617	0.954	1.00	1.065	1.065	−0.065
Dec.	0.639	0.988	2.96	0.384	1.138	1.822
Year	*1.398*	*2.167*	*48.71*	*.604*	*29.426*	*19.284*
1905.						
Jan.	2.266	3.512	4.75	.853	4.049	0.701
Feb.	0.588	0.909	1.72	.550	0.946	0.774
Mar.	2.950	4.563	3.69	1.425	5.260	−1.570
Apr.	2.572	3.976	2.70	1.642	4.435	−1.735
May	0.633	0.979	0.99	1.139	1.128	−0.138
June	0.378	0.584	2.99	.217	0.651	2.339
July	0.471	0.729	5.96	.141	0.840	5.120
Aug.	0.232	0.359	5.54	.747	0.414	5.126
Sept.	1.806	2.800	8.89	.351	3.124	5.766
Oct.	0.667	1.032	2.94	.404	1.189	1.751
Nov.	0.621	0.961	1.86	.576	1.072	0.788
Dec.	0.969	1.499	4.16	.415	1.727	2.433
Year	*1.183*	*1.825*	*46.19*	*.538*	*24.835*	*21.355*
1906.						
Jan.	1.149	1.779	2.64	0.776	2.050	0.590
Feb.	0.731	1.131	2.43	0.485	1.178	1.252
Mar.	1.633	2.522	4.45	0.653	2.908	1.542
Apr.	3.004	4.642	5.37	0.964	5.179	0.191
May	1.387	2.150	5.45	0.455	2.479	2.971
June	0.624	0.965	3.34	0.322	1.076	2.264
July	0.518	0.801	6.51	0.142	0.923	5.587
Aug.	0.312	0.483	2.59	0.215	0.557	2.033
Sept.	0.187	0.289	2.99	0.107	0.322	2.668
Oct.	0.680	1.052	2.80	0.433	1.213	1.587
Nov.	0.738	1.142	3.01	0.423	1.274	1.736
Dec.	0.748	1.157	3.66	0.364	1.333	2.327
Year	*0.976*	*1.509*	*45.24*	*.453*	*20.492*	*24.748*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1907.						
Jan.	1.303	2.011	2.92	0.794	2.318	0.602
Feb.	0.543	0.840	1.62	0.540	0.875	0.745
Mar.	2.327	3.604	1.96	2.120	4.155	−2.195
Apr.	1.480	2.289	2.49	1.025	2.553	−0.063
May	1.232	1.903	3.77	0.582	2.193	1.577
June	0.976	1.510	4.54	0.371	1.685	2.855
July	0.300	0.464	2.85	0.188	0.535	2.315
Aug.	0.095	0.147	1.73	0.977	0.169	1.561
Sept.	1.534	2.667	11.58	0.257	2.975	8.605
Oct.	2.247	3.481	6.70	0.599	4.013	2.687
Nov.	3.134	4.842	6.59	0.820	5.403	1.187
Dec.	1.610	2.491	4.91	0.585	2.872	2.038
Year	*1.402*	*2.180*	*51.66*	*0.579*	*29.746*	*21.914*
1908.						
Jan.	1.778	2.751	3.41	.930	3.17	0.24
Feb.	1.463	2.263	4.84	.504	2.44	2.40
Mar.	2.472	3.825	3.44	1.282	4.41	−0.97
Apr.	1.945	3.009	3.19	1.052	3.36	−0.17
May	2.844	4.400	7.19	.706	5.07	2.12
June	0.737	1.140	1.70	.748	1.27	0.43
July	0.420	0.649	4.40	.170	0.75	3.65
Aug.	0.343	0.530	4.10	.149	0.61	3.49
Sept.	0.170	0.269	1.85	.158	0.29	1.56
Oct.	0.238	0.368	2.62	.162	0.42	2.20
Nov.	0.253	0.391	1.02	.428	0.43	0.59
Dec.	0.275	0.425	2.91	.168	0.49	2.42
Year	*1.078*	*1.668*	*40.67*	*.558*	*22.71*	*17.96*
1909.						
Jan.	0.683	1.056	4.33	.281	1.02	3.31
Feb.	2.072	3.206	6.41	.521	3.34	3.07
Mar.	2.391	3.699	5.29	.805	4.26	1.03
Apr.	3.812	5.898	6.45	1.020	6.58	−0.13
May	1.559	2.412	4.00	.695	2.78	1.22
June	0.736	1.107	3.12	.407	1.27	1.85
July	0.126	0.194	1.16	.193	0.22	0.94
Aug.	0.287	0.444	4.70	.109	0.51	4.19
Sept.	0.305	0.471	4.36	.121	0.53	3.83
Oct.	0.179	0.276	1.32	.242	0.32	1.00
Nov.	0.193	0.298	2.34	.142	0.33	2.01
Dec.	0.426	0.659	3.64	.209	0.76	2.88
Year	*1.064*	*1.643*	*47.12*	*.465*	*21.92*	*25.20*
1910.						
Jan.	2.425	3.751	7.97	.543	4.33	3.64
Feb.	0.888	1.374	6.88	.208	1.43	5.45
Mar.	3.687	5.705	1.60	4.110	6.57	−4.97
Apr.	2.891	4.473	5.36	.931	4.99	0.37
May	1.397	2.161	3.58	.696	2.49	1.09
June	1.195	1.849	3.70	.557	2.06	1.64
July	0.134	0.207	1.67	.143	0.24	1.43
Aug.	0.251	0.388	4.48	.010	0.45	4.03
Sept.	0.194	0.300	3.07	.109	0.33	2.74
Oct.	0.131	0.202	0.72	.325	0.23	0.49
Nov.	0.452	0.699	5.59	.139	0.78	4.81
Dec.	0.262	0.405	1.87	.250	0.46	1.41
Year	*1.159*	*1.793*	*46.49*	*.524*	*24.36*	*22.13*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1911.						
Jan.	0.354	0.574	2.08	.296	0.62	1.46
Feb.	0.209	0.323	1.80	.183	0.33	1.47
Mar.	1.306	2.020	4.21	.540	2.27	1.94
Apr.	1.761	2.724	2.61	1.137	2.97	−0.36
May	0.566	0.875	1.13	.872	0.98	0.15
June	0.856	1.324	4.21	.342	1.44	2.77
July	0.422	0.653	4.17	.176	0.73	3.44
Aug.	0.404	0.625	6.71	.105	0.70	6.01
Sept.	0.294	0.455	4.57	.108	0.49	4.08
Oct.	2.433	3.764	8.86	.478	4.24	4.62
Nov.	1.352	2.092	2.57	.887	2.28	0.29
Dec.	1.026	1.587	2.98	.600	1.79	1.19
Year	*0.915*	*1.461*	*45.90*	*.410*	*18.84*	*27.06*
1912.						
Jan.	0.729	1.128	3.65	.356	1.300	2.350
Feb.	0.698	1.080	3.12	.373	1.165	1.955
Mar.	2.663	4.115	5.39	.880	4.744	0.646
Apr.	3.045	4.718	3.26	1.645	5.263	−2.003
May	1.733	2.676	4.60	.671	3.085	1.515
June	0.461	0.713	0.80	.884	0.795	0.005
July	0.151	0.234	2.43	.111	0.269	2.161
Aug.	0.218	0.337	4.96	.078	0.388	4.572
Sept.	0.211	0.326	3.375	.107	0.363	3.012
Oct.	0.725	1.121	5.79	.223	1.293	4.497
Nov.	1.017	1.578	4.24	.415	1.760	2.480
Dec.	1.124	1.732	4.70	.425	1.997	2.703
Year	*1.065*	*1.646*	*46.315*	*.484*	*22.422*	*23.893*
1913.						
Jan.	1.735	2.692	3.61	.860	3.104	0.506
Feb.	0.901	1.394	2.32	.626	1.452	0.868
Mar.	3.026	4.687	5.78	.935	5.403	0.377
Apr.	2.126	3.295	3.95	.931	3.676	0.274
May	1.317	2.042	5.19	.454	2.355	2.835
June	0.374	0.578	0.67	.961	0.644	0.026
July	0.110	0.170	1.88	.104	0.196	1.684
Aug.	0.066	0.102	2.37	.049	0.117	2.253
Sept.	0.203	0.314	3.44	.102	0.351	3.089
Oct.	0.738	1.142	6.77	.194	1.316	5.454
Nov.	0.665	1.025	3.74	.306	1.143	2.597
Dec.	0.934	1.445	3.06	.544	1.666	1.394
Year	*1.061*	*1.574*	*42.78*	*.501*	*21.423*	*21.357*
1914.						
Jan.	0.528	0.817	3.21	.293	0.942	2.268
Feb.	0.835	1.292	5.65	.238	1.345	4.305
Mar.	2.388	3.697	4.32	.987	4.262	0.058
Apr.	3.715	5.755	5.13	1.252	6.421	−1.291
May	2.007	3.109	4.005	.897	3.595	0.410
June	0.302	0.467	2.01	.259	0.521	1.489
July	0.291	0.450	3.18	.163	0.519	2.661
Aug.	0.161	0.249	3.20	.089	0.286	2.914
Sept.	0.073	0.113	0.185	.681	0.126	0.059
Oct.	0.119	0.184	2.03	.105	0.213	1.817
Nov.	0.239	0.370	3.32	.124	0.413	2.907
Dec.	0.295	0.456	3.14	.167	0.526	2.614
Year	*0.912*	*1.413*	*39.38*	*.487*	*19.169*	*20.211*

YIELD OF SOUTHWEST BRANCH OF MANHAN RIVER. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1915.						
Jan.	1.586	2.459	6.605	.429	2.835	3.770
Feb.	2.211	3.419	5.575	.637	3.560	2.015
Mar.	1.121	1.733	0.15	13.313	1.997	−1.847
Apr.	1.751	2.707	3.97	.760	3.020	0.950
May	0.939	1.453	2.27	.738	1.676	0.594
June	0.351	0.543	2.43	.249	0.606	1.824
July	2.111	3.264	8.96	.420	3.763	5.197
Aug.	2.917	4.517	9.82	.530	5.208	4.612
Sept.	0.353	0.546	2.08	.293	0.609	1.471
Oct.	0.309	0.478	2.01	.274	0.551	1.459
Nov.	1.450	2.243	3.41	.734	2.502	0.908
Dec.	1.450	2.243	5.42	.479	2.586	2.834
Year	*1.377*	*2.130*	*52.70*	*.549*	*28.913*	*23.787*
1916.						
Jan.	1.577	2.444	1.81	1.557	2.818	−1.008
Feb.	2.953	4.564	6.44	.769	4.923	1.517
Mar.	1.578	2.444	2.83	.995	2.818	0.012
Apr.	3.922	6.064	4.44	1.524	6.766	−2.326
May	1.619	2.506	3.24	.892	2.889	0.351
June	1.549	2.398	5.89	.454	2.676	3.214
July	0.670	1.036	5.42	.220	1.194	4.226
Aug.	0.313	0.484	2.06	.271	0.558	1.502
Sept.	0.494	0.764	8.04	.106	0.853	7.187
Oct.	0.376	0.582	1.55	.434	0.672	0.878
Nov.	0.810	1.253	3.79	.368	1.399	2.391
Dec.	0.926	1.433	2.97	.556	1.653	1.317
Year	*1.387*	*2.164*	*48.48*	*.599*	*29.219*	*19.261*
1917.						
Jan.	1.134	1.748	4.57	.441	2.015	2.555
Feb.	0.572	0.885	2.36	390	0.921	1.439
Mar.	2.116	3.280	4.19	.902	3.781	0.409
Apr.	2.378	3.682	2.24	1.834	4.109	−1.869
May	1.941	3.001	3.40	1.018	3.460	−0.060
June	1.571	2.429	5.23	.518	2.710	2.520
July	0.425	0.657	1.84	.411	0.757	1.083
Aug.	0.202	0.312	3.07	.117	0.360	2.710
Sept.	0.116	0.179	0.72	.277	0.200	0.520
Oct.	0.975	1.508	9.37	.186	1.739	7.631
Nov.	0.564	0.872	1.03	.963	0.974	0.056
Dec.	0.479	0.741	4.30	.199	0.854	3.446
Year	*1.042*	*1.608*	*42.32*	*.517*	*21.880*	*20.440*
1918.						
Jan.	0.462	0.715	3.81	.216	0.825	2.985
Feb.	0.900	1.392	1.85	.784	1.450	0.400
Mar.	3.247	5.028	1.58	3.669	5.797	−4.217
Apr.	2.253	3.481	2.90	1.339	3.884	−0.984
May	1.249	1.934	2.86	.779	2.230	0.630
June	0.538	0.832	4.30	.216	0.929	3.371
July	0.273	0.422	2.88	.169	0.486	2.394
Aug.	0.260	0.402	3.84	.121	0.463	3.377
Sept.	0.519	0.803	6.67	.134	0.897	5.773
Oct.	0.275	0.425	1.43	.342	0.489	0.941
Nov.	0.521	0.806	2.93	.307	0.900	2.030
Dec.	1.003	1.547	3.47	.514	1.783	1.687
Year	*0.960*	*1.482*	*38.52*	*.523*	*20.133*	*18.387*

Yield of Southwest Branch of Manhan River. — *Continued.*

Month.	Per Sq. Mile.		Precip. Inches.	Per Cent. Run-off.	Stream Yield. Inches.	Apparent Water Loss. In.
	M.G.D.	C.F.S.				
1919.						
Jan.	0.957	1.480	2.30	.724	1.766	0.594
Feb.	0.503	0.788	3.25	.251	10.820	2.430
Mar.	2.853	4.409	6.13	.829	5.082	1.048
Apr.	1.996	3.094	2.54	1.360	3.455	−0.915
May	2.519	3.898	8.38	.536	4.493	3.887
June	0.786	1.216	1.75	.775	1.357	0.393
July	0.350	0.541	4.66	.134	0.625	4.035
Aug.	0.213	0.329	3.00	.126	0.378	2.622
Sept.	0.451	0.698	4.02	.193	0.779	3.241
Oct.	0.332	0.514	2.56	.232	0.593	1.967
Nov.	1.296	2.011	5.75	.390	2.244	3.506
Dec.	1.006	1.562	2.06	.875	1.802	0.258
Year	*1.110*	*1.712*	*46.40*	*.503*	*23.334*	*23.066*

Watuppa Pond Supply Streams, Fall River, Mass.

These records, furnished by Prof. H. K. Barrows, consulting engineer, of Boston, Mass., are published as much because of the light which they shed on the variations to be expected in the run-off of very small adjacent drainage basins as for their intrinsic value for water-works estimates; furthermore, it so happens that in this case two independent investigations have been made covering the same streams, both by able engineers, thus affording a comparison between two independent sets of results.

The records obtained in the first series of studies are contained in the report of Arthur T. Safford to the Reservoir Commission of the City of Fall River, published July, 1902. The results are summarized in the Journal of the N. E. W. W. Association, Vol. 33, pages 326–329, and the rainfall records are discussed in the Journal of the N. E. W. W. Association, Vol. 33, page 61.

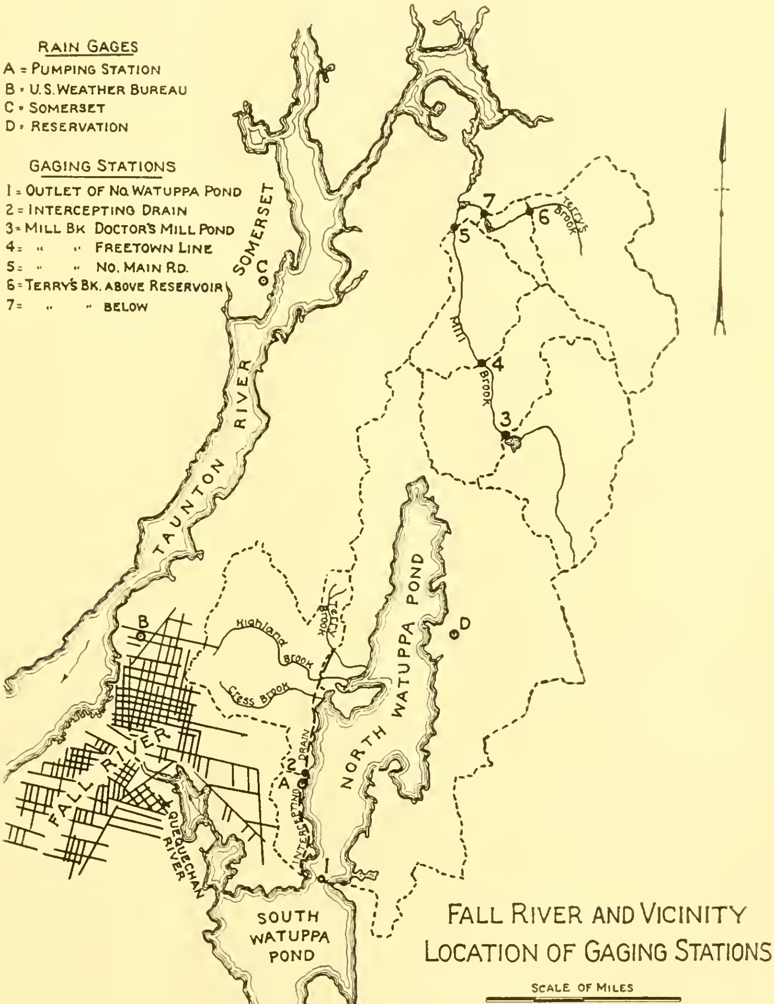
The accompanying map and notes show the locations of the weirs and rainfall stations used in the later investigations. It will be noted that there are considerable differences in the depth of run-off of adjacent basins or adjacent weirs, subject to practically the same precipitation. Similar differences were found in the earlier investigations by Professor Safford, and are undoubtedly due in some degree at least to watershed leakage from higher to lower levels, since in general the lower lying basins show the larger yields, particularly in the Safford results. This in spite of the fact that the lower lying basins were often more swampy, and would apparently be subject to greater water losses.

The location and topography of the various drainage basins are shown on the Fall River, Mass., sheet of the U. S. Geological Survey, topographic maps.

Memorandum Accompanying Data of Run-off and Precipitation for Stations in Vicinity of Fall River, Mass.

General Note.

The location of rain gages and gaging stations is shown on accompanying map. The stream-gaging stations have been maintained under the direction of the Reservoir Commission of the City of Fall River, and the



FALL RIVER AND VICINITY
LOCATION OF GAGING STATIONS

records furnished through their courtesy by H. K. Barrows, consulting engineer. The precipitation stations in the vicinity of North Watuppa Pond, viz., at the pumping station and reservation, are also maintained by the Reservoir Commission. The other precipitation stations, viz., at Fall River and Somerset, are maintained by the U. S. Weather Bureau.

Precipitation Records.

Precipitation records for 1916 to 1919, inclusive, are shown on appended sheet. As will be noted, there is considerable difference in the recorded results at these several stations. In making studies in this vicinity, as a rule the precipitation records at the pumping station have been used, as these are carefully kept and the exposure of the gage is fairly good. The gage on the Reservation has only been in use a little over a year, but so far seems to indicate a somewhat higher precipitation than that at the pumping station. In general, also, the Weather Bureau gage at Fall River shows a higher precipitation than that observed at the pumping station.

The Somerset gage has a very poor exposure, with several obstructions in the way of trees and buildings quite close to it. The Weather Bureau gage at Fall River is better located, but not entirely free from the effect of obstructions in the vicinity. The Reservation gage is well located in a large field.

Gaging Stations.

Intercepting Drain near Pumping Station. In 1915, an intercepting drain, chiefly of reinforced concrete, was built along the west shore of North Watuppa Pond, as shown on the map, to divert directly to the South Watuppa Pond drainage from the Highland, Terry, and Cress Brook districts. Beginning with 1917, records of the flow through the drain have been obtained by weir measurements at a point near the pumping station, where the drainage area is 1.94 square miles. The weir is placed centrally in a section of the intercepting drain which is open and 10 ft. wide, the crest of the weir being 10 in. above the invert of the drain. For the larger flows current meter measurements have been made, and a rating curve developed.

This drainage area is about two thirds wooded, with either trees or bushes, about one sixth cultivated land with buildings and streets, and the remaining one sixth is swamp area. The underlying soil is hard pan and fairly impervious. Care was taken in constructing the intercepting drain to prevent as far as possible any seepage of water under the drain to the North Pond.

Mill Brook Gaging Stations. The drainage area of Mill Brook is almost entirely wooded, with a little swamp area, most of which is above the Doctor's Mill Pond weir. The underlying soil is sand in the form of glacial drift, although at some little depth the sand becomes very fine, with traces of clay.

Doctor's Mill Pond Weir. Measurements are made by a sharp crested weir placed in the flume of the old dam. There is some leakage by the weir, which is measured by means of a small auxiliary triangular notch weir. The drainage area at Doctor's Mill Pond weir is 1.88 sq. mi.

PRECIPITATION — FALL RIVER VICINITY, 1916–19, INCLUSIVE.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1916.													
Pumping Station	1.47	4.72	3.22	4.29	4.31	3.72	9.85	2.20	1.06	2.11	1.93	4.65	43.53
U. S. Weather Bureau	1.48	5.14	3.77	4.78	4.78	3.90	11.47	2.03	1.28	3.01	3.14	3.71	48.49
Somerset	1.41	4.39	2.92	4.00	3.74	4.29	10.66	1.31	1.12	2.29	2.79	3.14	42.06
1917.													
Pumping Station	2.44	2.91	5.08	3.33	4.98	4.79	1.33	3.03	2.89	4.67	0.37	2.03	37.85
U. S. Weather Bureau	3.63	2.73	5.04	3.17	4.77	4.63	1.21	3.75	2.93	5.69	0.45	3.10	41.10
Somerset	2.87	2.55	3.87	3.04	5.20	4.33	1.12	3.95	2.95	5.95	0.24	1.80	37.87
1918.													
Pumping Station	3.17	2.86	2.04	4.92	1.90	3.06	2.71	3.44	3.55	0.82	2.00	3.49	33.96
U. S. Weather Bureau	4.01	3.56	2.46	5.51	2.00	3.24	2.51	3.98	4.42	1.08	2.32	4.08	39.17
Somerset	3.33	2.88	2.52	4.09	1.72	2.40	3.16	2.08	3.81	0.90	2.02	2.74	31.65
1919.													
Pumping Station	5.53	3.77	3.90	3.00	4.18	2.08	5.06	6.41	6.81	2.12	3.88	2.89	49.63
U. S. Weather Bureau	5.07	3.80	5.29	3.24	4.62	1.93	5.52	7.26	7.48	2.51	3.71	2.33	52.76
Somerset	4.76	3.87	4.22	3.04	4.30	1.84	5.47	6.74	7.10	2.82	4.07	2.54	46.47
Reservation	5.18	4.05	5.22	3.56	5.19	2.33	5.41	7.57	6.45	2.46	4.52	2.72	54.66

YIELD AT TERRY'S BROOK NO. 1, ABOVE RESERVOIR, FALL RIVER, MASS.
Drainage Area, 1.83 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile. M.G.P.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
1917.							
Jan.	4.00	1.41	2.19	2.44	2.52	−0.08	1.04
Feb.	3.00	1.06	1.64	2.91	1.70	1.21	.59
Mar.	7.23	2.55	3.95	5.08	4.55	0.53	.12
Apr.	6.47	2.29	3.54	3.33	3.94	−0.61	1.18
May	5.57	1.96	3.04	4.98	3.51	1.47	.71
June	5.22	1.85	2.85	4.79	3.18	1.61	.66
July	0.84	0.30	0.46	1.33	0.53	0.80	.40
Aug.	0.42	0.15	0.23	3.03	0.27	2.76	.09
Sept.	0.22	0.08	0.12	2.89	0.14	2.75	.05
Oct.	1.23	0.43	0.67	4.67	0.77	3.90	.17
Nov.	1.19	0.42	0.65	0.37	0.72	−0.35	1.96
Dec.	1.86	0.66	1.02	2.03	1.17	0.86	.58
Year	*3.10*	*1.10*	*1.70*	*37.85*	*23.00*	*14.85*	*.608*
1918.							
Jan.	2.13*	0.75*	1.17*	3.17	1.34*	1.83*	.42
Feb.	4.14	1.46	2.26	2.86	2.35	0.51	.82
Mar.	2.85	1.01	1.56	2.04	1.79	0.25	.88
Apr.	5.12	1.81	2.80	4.92	3.12	1.80	.64
May	2.72	0.96	1.49	1.90	1.72	0.18	.91
June	1.28	0.45	0.70	3.06	0.78	2.28	.26
July	0.32	0.11	0.18	2.71	0.20	2.51	.08
Aug.	0.23	0.08	0.13	3.44	0.15	3.29	.05
Sept.	0.21	0.07	0.11	3.55	0.13	3.42	.04
Oct.	0.10	0.03	0.05	0.82	0.06	0.76	.08
Nov.	0.31	0.11	0.17	2.00	0.19	1.81	.10
Dec.	1.82	0.65	1.00	3.49	1.15	2.34	.33
Year	*1.77*	*0.62*	*0.97*	*33.96*	*12.98*	*20.98*	*.382*
1919.							
Jan.	4.05	1.43	2.21	5.53	2.55	2.98	.46
Feb.	5.04	1.78	2.76	3.77	2.87	0.90	.76
Mar.	6.75	2.38	3.69	3.90	4.25	−0.35	1.09
Apr.	5.31	1.87	2.90	3.00	3.24	−0.24	1.08
May	5.4	1.91	2.95	4.18	3.40	0.78	.82
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year	...	...	...	*49.63*	...	...	...

* Estimated.

Mill Brook at Freetown Line. Measurements in general have been made by current meter and rating curve, although in the low water season a triangular notch weir has been used most of the time. Drainage area, 3.35 sq. mi.

Mill Brook at North Main Road. Measurements made by current meter and rating curve, except a portion of the time during a low water season, when a 2-ft. rectangular weir is used. Drainage area, 4.39 sq. mi.

Terry's Brook Gaging Stations. The drainage area is nearly all wooded, with a small amount of swamp and water area.

Terry's Brook No. 1, above the Reservoir. Measurements were made partly by current meter and rating curve and partly by weir. Drainage area, 1.83 sq. mi.

Terry's Brook No. 2, below the Reservoir. Measurements made by current meter and rating curve. The station is about 100 ft. below the spillway of the upper reservoir of the Crystal Spring Bleachery, a small reservoir used simply for storage purposes. Drainage area, 2.19 sq. mi.

All these records are published as taken, without reduction to basis of yield of net land area.

Yield at Terry's Brook No. 2, Crystal Springs, below Reservoir, Fall River Mass.

Drainage Area, 2.19 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile.		Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
		M.G.P.	C.F.S.				
1917.							
Jan.	4.19	1.23	1.91	2.44	2.20	0.24	.90
Feb.	2.70	0.79	1.23	2.91	1.29	1.62	.45
Mar.	6.23	1.83	2.84	5.08	3.28	1.80	.65
Apr.	5.56	1.64	2.54	3.33	2.82	0.51	.85
May	5.48	1.62	2.50	4.98	2.88	2.10	.58
June	4.77	1.41	2.18	4.79	2.43	2.36	.51
July	1.23	0.36	0.56	1.33	0.65	0.68	.49
Aug.	1.04	0.31	0.47	3.03	0.55	2.48	.18
Sept.	1.62	0.48	0.74	2.89	0.83	2.06	.29
Oct.	1.15	0.34	0.53	4.67	0.61	4.06	.13
Nov.	1.62	0.48	0.74	0.37	0.82	−0.45	2.22
Dec.	1.67	0.49	0.76	2.03	0.88	1.15	.44
Year	*3.11*	*0.92*	*1.42*	*37.85*	*19.24*	*18.61*	*.508*
1918.							
Jan.	3.01	0.89	1.37	3.17	1.58	1.59	.50
Feb.	4.38	1.29	2.00	2.86	2.08	0.78	.73
Mar.	3.66	1.08	1.67	2.04	1.93	0.11	.95
Apr.	4.61	1.36	2.10	4.92	2.35	2.57	.48
May	2.40	0.71	1.10	1.90	1.26	0.64	.66
June	1.08	0.32	0.49	3.06	0.53	2.53	.17
July	0.51	0.15	0.23	2.71	0.27	2.44	.10
Aug.	0.18	0.05	0.08	3.44	0.10	3.34	.03
Sept.	0.31	0.09	0.14	3.55	0.16	3.39	.05
Oct.	0.18	0.05	0.08	0.82	0.09	0.73	.11
Nov.	0.00	0.00	0.00	2.00	0.00	2.00	0.00
Dec.	1.57	0.46	0.72	3.49	0.83	2.66	.24
Year	*1.82*	*0.54*	*0.83*	*33.96*	*11.18*	*22.78*	*.328*
1919.							
Jan.	6.33	1.87	2.89	5.53	3.34	2.19	.60
Feb.	5.09	1.50	2.32	3.77	2.42	1.35	.64
Mar.	6.47	1.91	2.96	3.90	3.42	0.48	.88
Apr.	5.33	1.57	2.43	3.00	2.71	0.29	.90
May	4.51	1.33	2.06	4.18	2.38	1.80	.57
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year	...	...	...	*49.63*	...	...	...

Yield of Mill Brook at Doctor's Mill Pond Weir, Fall River, Mass.
Drainage Area, 1.88 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile. M.G.P.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss In.	Per Cent. Run-off.
1916.							
Jan.	2.56	0.88	1.36	1.47	1.57	−0.10	1.07
Feb.	2.52	0.87	1.34	4.72	1.45	3.27	.31
Mar.	4.00	1.38	2.13	3.22	2.46	0.76	.77
Apr.	6.04	2.08	3.22	4.29	3.59	0.70	.84
May	5.92	2.04	3.15	4.31	3.64	0.67	.84
June	5.08	1.75	2.70	3.72	3.02	0.70	.81
July	7.81	2.69	4.15	9.85	4.79	5.06	.49
Aug.	2.27	0.78	1.21	2.20	1.40	0.80	.64
Sept.	0.29	0.10	0.15	1.06	0.17	0.89	.16
Oct.	0.64	0.22	0.34	2.11	0.39	1.72	.19
Nov.	0.88	0.30	0.47	1.93	0.52	1.41	.27
Dec.	2.52	0.87	1.34	4.65	1.54	3.11	.33
Year	*3.38*	*1.16*	*1.80*	*43.53*	*24.54*	*18.99*	*.564*
1917.							
Jan.	3.33	1.14	1.77	2.44	2.04	0.40	.84
Feb.	2.29	0.79	1.22	2.91	1.27	1.64	.44
Mar.	6.67	2.29	3.55	5.08	4.08	1.00	.80
Apr.	6.51	2.23	3.46	3.33	3.86	−0.53	1.16
May	6.03	2.07	3.21	4.98	3.68	1.30	.74
June	5.10	1.75	2.71	4.79	3.02	1.77	.63
July	1.20	0.41	0.64	1.33	0.73	0.60	.55
Aug.	0.41	0.14	0.22	3.03	0.25	2.78	.08
Sept.	0.35	0.12	0.19	2.89	0.21	2.68	.07
Oct.	1.53	0.52	0.81	4.67	0.94	3.73	.20
Nov.	1.43	0.49	0.76	0.37	0.85	−0.48	2.31
Dec.	1.82	0.63	0.97	2.03	1.11	0.92	.55
Year	*3.06*	*1.05*	*1.63*	*37.85*	*22.04*	*15.81*	*.582*
1918.							
Jan.	2.68*	0.92*	1.42*	3.17	1.64*	1.53	.52
Feb.	7.74*	2.66*	4.12*	2.86	4.29*	−1.43	1.50
Mar.	4.72	1.62	2.51	2.04	2.90*	−0.86	1.42
Apr.	6.41	2.20	3.41	4.92	3.80	1.12	.77
May	3.16	1.08	1.68	1.90	1.94	−0.04	1.02
June	1.61	0.55	0.85	3.06	0.96	2.10	.32
July	0.44	0.15	0.23	2.71	0.27	2.44	.10
Aug.	0.54	0.19	0.29	3.44	0.33	3.11	.10
Sept.	0.31	0.11	0.16	3.55	0.18	3.37	.05
Oct.	0.27	0.09	0.14	0.82	0.17	0.65	.22
Nov.	0.59	0.20	0.31	2.00	0.35	1.65	.18
Dec.	2.08	0.72	1.11	3.49	1.28	2.21	.37
Year	*2.56*	*0.87*	*1.35*	*33.96*	*18.11*	*15.81*	*.533*
1919.							
Jan.	4.59	1.58	2.44	5.53	2.82	2.71	.51
Feb.	4.24	1.45	2.25	3.77	2.35	1.42	.63
Mar.	6.48	2.23	3.44	3.90	3.97	−0.07	1.02
Apr.	5.48	1.88	2.82	3.00	3.26	−0.26	1.09
May	5.17	1.78	2.75	4.18	3.18	1.00	.76
June	1.23	0.42	0.65	2.08	0.73	1.35	.35
July	1.58	0.54	0.84	5.06	0.97	4.09	.19
Aug.	2.15	0.74	1.14	6.41	1.32	5.09	.21
Sept.	5.89	2.02	3.13	6.81	3.50	3.31	.51
Oct.	1.97	0.68	1.05	2.12	1.21	0.91	.57
Nov.	3.28	1.12	1.74	3.88	1.95	1.93	.50
Dec.	4.84	1.66	2.57	2.89	2.97	−0.08	1.03
Year	*3.90*	*1.34*	*2.07*	*49.63*	*28.23*	*21.40*	*.569*

* Estimated.

Yield of Mill Brook at North Main Road, Assonet, Fall River, Mass.
Drainage Area, 4.39 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile. M.G.P.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
1916.							
Jan.	...	...	...	1.47	...	...	...
Feb.	...	...	...	4.72	...	...	...
Mar.	...	...	...	3.22	...	...	...
Apr.	...	...	...	4.29	...	...	...
May	12.4	1.83	2.83	4.31	3.26	1.05	.76
June	10.7	1.58	2.44	3.72	2.72	1.00	.73
July	17.6	2.59	4.00	9.85	4.61	5.24	.47
Aug.	4.45	0.65	1.01	2.20	1.17	1.03	.53
Sept.	0.90	0.13	0.20	1.06	0.23	.83	.22
Oct.	1.89	0.28	0.43	2.11	0.50	1.61	.24
Nov.	2.32	0.34	0.53	1.93	0.59	1.34	.31
Dec.	6.05	0.89	1.38	4.65	1.59	3.06	.34
Year	...	...	...	*43.53*	...	...	...
1917.							
Jan.	8.92	1.31	2.03	2.44	2.34	0.10	.96
Feb.	6.14	0.90	1.40	2.91	1.45	1.46	.50
Mar.	15.45	2.27	3.52	5.08	4.06	1.02	.80
Apr.	12.87	1.89	2.93	3.33	3.27	0.06	.98
May	11.89	1.75	2.70	4.98	3.12	1.86	.63
June	11.39	1.68	2.60	4.79	2.89	1.90	.60
July	2.24	0.33	0.51	1.33	0.59	0.74	.45
Aug.	0.68	0.10	0.16	3.03	0.18	2.85	.06
Sept.	0.84	0.12	0.19	2.89	0.21	2.68	.07
Oct.	3.27	0.48	0.74	4.67	0.86	3.81	.19
Nov.	3.02	0.45	0.69	0.37	0.77	−0.40	2.08
Dec.	9.60	1.42	2.19	2.03	2.52	−0.49	1.25
Year	*7.19*	*1.06*	*1.64*	*37.85*	*22.26*	*15.59*	*.588*
1918.							
Jan.	7.14*	1.05*	1.62*	3.17	1.88*	1.29	.59
Feb.	20.73	3.05	4.72	2.86	4.92	−2.06	1.72
Mar.	10.79	1.59	2.46	2.04	2.83	−0.79	1.39
Apr.	14.82	2.18	3.38	4.92	3.77	1.15	.77
May	6.56	0.96	1.49	1.90	1.72	0.18	.91
June	3.06	0.45	0.70	3.06	0.78	2.28	.26
July	0.77	0.11	0.18	2.71	0.20	2.51	.08
Aug.	0.87	0.13	0.20	3.44	0.23	3.21	.07
Sept.	0.77	0.11	0.17	3.55	0.19	3.36	.06
Oct.	0.64	0.09	0.15	0.82	0.17	0.65	.21
Nov.	1.55	0.23	0.35	2.00	0.39	1.61	.20
Dec.	4.67	0.69	1.06	3.49	1.22	2.27	.35
Year	*6.03*	*0.89*	*1.37*	*33.96*	*18.30*	*15.66*	*.539*
1919.							
Jan.	14.81	2.18	3.37	5.53	3.89	1.64	.70
Feb.	13.22	1.94	3.01	3.77	3.14	0.63	.83
Mar.	14.44	2.12	3.29	3.90	3.79	0.11	.97
Apr.	12.08	1.77	2.75	3.00	3.06	−0.06	1.01
May	11.6	1.71	2.64	4.18	3.05	1.13	.73
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year	...	...	...	*49.63*	...	...	...

* Estimated.

Yield at Weir on Fall River, Intercepting Drain near Pumping Station, Fall River, Mass.

Drainage Area, 1.94 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile. M.G.P.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
1917.							
Jan.......	2.74	0.91	1.41	2.44	1.62	0.82	.67
Feb.......	2.22	0.74	1.14	2.91	1.19	1.72	.41
Mar.......	6.80	2.27	3.51	5.08	4.04	1.04	.80
Apr.......	5.24	1.74	2.70	3.33	3.02	0.31	.91
May......	5.50	1.83	2.84	4.98	3.28	1.70	.66
June......	4.42	1.47	2.28	4.79	2.55	2.24	.53
July......	1.14	0.38	0.59	1.33	0.68	0.65	.52
Aug.......	0.554	0.19	0.29	3.03	0.33	2.70	.11
Sept.......	0.43	0.14	0.22	2.89	0.25	2.64	.09
Oct.......	1.48	0.49	0.76	4.67	0.88	3.79	.19
Nov.......	1.34	0.45	0.69	0.37	0.77	−0.40	2.08
Dec.......	1.61	0.54	0.83	2.03	0.95	1.08	.47
Year......	*2.79*	*0.93*	*1.44*	*37.85*	*19.56*	*18.29*	*.517*
1918.							
Jan.......	2.06*	0.68*	1.06*	3.17	1.23*	1.94	.39
Feb.......	3.74*	1.25*	1.93*	2.86	2.00*	0.86	.70
Mar.......	4.01	1.33	2.06	2.04	2.38	−0.34	1.17
Apr.......	5.72	1.90	2.94	4.92	3.28	1.64	.67
May......	2.44	0.82	1.26	1.90	1.46	0.44	.77
June......	1.12	0.37	0.58	3.06	0.65	2.41	.21
July......	0.28	0.09	0.14	2.71	0.17	2.54	.07
Aug.......	0.41	0.14	0.21	3.44	0.24	3.20	.07
Sept.......	0.23	0.08	0.12	3.55	0.13	3.42	.04
Oct.......	0.14	0.05	0.07	0.82	0.09	0.73	.11
Nov.......	0.43	0.14	0.22	2.00	0.25	1.75	.13
Dec.......	1.42	0.47	0.73	3.49	0.84	2.65	.24
Year......	*1.83*	*0.61*	*0.94*	*33.96*	*12.72*	*21.24*	*.375*
1919.							
Jan.......	4.12	1.37	2.12	5.53	2.44	3.09	.44
Feb.......	4.27	1.42	2.20	3.77	2.29	1.48	.61
Mar.......	6.86	2.29	3.54	3.90	4.08	−0.18	1.05
Apr.......	5.28	1.75	2.71	3.00	3.04	−0.04	1.01
May......	4.50	1.50	2.32	4.18	2.68	1.50	.64
June......	0.98	0.33	0.51	2.08	0.57	1.51	.27
July......	1.23	0.42	0.63	5.06	0.73	4.33	.15
Aug.......	2.35	0.78	1.21	6.41	1.40	5.01	.22
Sept.......	5.70	1.91	2.94	6.81	3.28	3.53	.48
Oct.......	2.23	0.74	1.15	2.12	1.32	0.80	.63
Nov.......	4.48	1.49	2.31	3.88	2.58	1.30	.67
Dec.......	3.30	1.10	1.70	2.89	1.96	0.93	.68
Year......	*3.77*	*1.25*	*1.94*	*49.63*	*26.37*	*23.26*	*.531*

* Estimated.

Yield of Mill Brook at Freetown Line, Fall River, Mass.
Drainage Area, 3.35 Sq. Mi.

Month.	Mean C.F.S.	Per Sq. Mile. M.G.P.	Per Sq. Mile. C.F.S.	Precip. Inches.	Stream Yield. Inches.	Apparent Water Loss. In.	Per Cent. Run-off.
1916.							
Jan.	...	...	...	1.47	...	...	...
Feb.	...	...	...	4.72	...	...	...
Mar.	...	...	...	3.22	...	...	...
Apr.	...	...	...	4.29	...	...	...
May	10.9	2.00	3.25	4.31	3.75	0.56	.87
June	8.41	1.63	2.51	3.72	2.80	0.92	.76
July	14.0	2.70	4.18	9.85	4.82	5.03	.49
Aug.	3.90	0.75	1.16	2.20	1.34	0.86	.61
Sept.	0.55	0.10	0.16	1.06	0.18	0.88	.17
Oct.	1.07	0.21	0.32	2.11	0.37	1.74	.18
Nov.	1.49	0.29	0.45	1.93	0.50	1.43	.26
Dec.	4.54	0.88	1.36	4.65	1.57	3.08	.34
Year	...	...	...	*43.53*	...	...	...
1917.							
Jan.	6.01	1.16	1.79	2.44	2.07	0.37	.85
Feb.	3.52	0.68	1.05	2.91	1.10	1.81	.38
Mar.	12.04	2.31	3.59	5.08	4.14	0.94	.82
Apr.	10.96	2.11	3.27	3.33	3.65	−0.32	1.10
May	10.86	2.09	3.24	4.98	3.73	1.25	.75
June	9.41	1.81	2.81	4.79	3.13	1.66	.65
July	1.84	0.36	0.55	1.33	0.63	0.70	.48
Aug.	0.84	0.16	0.25	3.03	0.29	2.74	.10
Sept.	0.71	0.14	0.21	2.89	0.24	2.65	.04
Oct.	2.88	0.56	0.86	4.67	0.99	3.68	.27
Nov.	2.56	0.49	0.76	0.37	0.85	−0.48	2.30
Dec.	3.13	0.60	0.93	2.03	1.08	0.95	.53
Year	*6.01*	*1.04*	*1.61*	*37.85*	*21.90*	*15.95*	*.578*
1918.							
Jan.	4.8*	0.93*	1.44*	3.17	1.66*	1.51	.53
Feb.	11.9*	2.30*	3.56*	2.86	3.71*	−0.85	1.30
Mar.	7.57	1.46	2.26	2.04	2.61	−0.57	1.28
Apr.	10.92	2.11	3.26	4.92	3.64	1.28	.74
May	6.25	1.21	1.87	1.90	2.15	−0.25	1.14
June	2.58	0.50	0.77	3.06	0.86	2.20	.28
July	0.57	0.11	0.17	2.71	0.20	2.51	.08
Aug.	0.81	0.16	0.24	3.44	0.28	3.16	.08
Sept.	0.48	0.09	0.14	3.55	0.16	3.39	.05
Oct.	0.40	0.08	0.12	0.82	0.14	0.68	.18
Nov.	0.97	0.19	0.29	2.00	0.32	1.68	.16
Dec.	4.08	0.79	1.22	3.49	1.41	2.08	.41
Year	*4.28*	*0.83*	*1.28*	*33.96*	*17.14*	*16.82*	*.505*
1919.							
Jan.	10.03	1.94	3.00	5.53	3.46	2.07	.63
Feb.	7.08	1.37	2.12	3.77	2.21	1.56	.59
Mar.	10.50	2.02	3.13	3.90	3.62	0.28	.93
Apr.	10.07	1.94	3.00	3.00	3.36	−0.36	1.12
May	12.55	2.42	3.75	4.18	4.32	−0.14	1.04
June	...	...	...	2.08	...	...	...
July	...	...	...	5.06	...	...	...
Aug.	...	...	...	6.41	...	...	...
Sept.	...	...	...	6.81	...	...	...
Oct.	...	...	...	2.12	...	...	...
Nov.	...	...	...	3.88	...	...	...
Dec.	...	...	...	2.89	...	...	...
Year	...	...	...	*49.63*	...	...	...

* Estimated.

Evaporation from Water Surfaces.

It was the intention of the committee to present, in conjunction with its report, available records of evaporation from water surfaces. Inasmuch, however, as a new Committee on Water Losses has been appointed by the New England Water Works Association, which will undoubtedly consider matters of evaporation in detail, and since the existing records would apparently require more discussion than would be appropriate here, to render them available for practical use, they have been omitted.

The following references to existing records of evaporation from water surfaces may, however, prove useful:

Rochester, N. Y.

This record gives the result of evaporation as measured in two fiber tubs, each 15 in. top diameter, 7½ in. deep, and with water surface about 3 in. below the rim. One tub is floated in Mt. Hope Reservoir, surrounded by a raft; the other tub stands on the raft. The available records for the floating tub cover generally the months April to October in the years 1891 to 1896, inclusive, and are complete for all months in subsequent years. The record for the tub exposed on the raft covers the months April to November, inclusive, from 1891 to date, with the exception of the first four years, for which certain months are missing. The records are accompanied by data showing mean temperature of water in each tub, rainfall, air temperature, and for the years subsequent to 1905 wind velocity is also given. The earlier results have been published in the annual reports of the Executive Board of the City of Rochester, and the later results in the reports of the Department of Engineering, Rochester, N. Y.

Maine Stations.

Records of evaporation at Millinocket, Lewiston, Mooselookmeguntic, Me., and Soldier Pond, Me., for summer periods in the years 1905 to 1908 inclusive, are contained in Water Supply Paper No. 279, "Water Resources of the Penobscot River Basin, Maine," by H. K. Barrows and C. C. Babb, pages 113–129. These records were obtained by means of floating pans, protected by raft, the pans being 3 ft. square and 18 in. deep. Weekly results are given, accompanied by data of water and air temperature, humidity, and wind velocity.

Boston, Mass.

Records of evaporation at Chestnut Hill Reservoir, Boston, and experimental data to determine the laws of evaporation, are contained in a paper by Desmond FitzGerald, Mem. Am. Soc. C. E., Trans. Am. Soc., Vol. 15, September, 1886, pages 581–646; also in a paper, "Rainfall, Flow of Streams, and Storage," same author, Trans. Am. Soc. C. E., Vol. 27, 1892.

Graefenburg Reservoir, Utica, N. Y.

Records of evaporation obtained from a 3-ft. square buried tank, depth 24 in., with rim 3 in. above ground, and water, covering the summer months of the years 1905–6–7, are given in the reports of the state engineer and surveyor of New York State, 1906 Supplement, pages 215–245, and 1907 report, pages 518–532.

Hartford, Conn.

Records of evaporation from land and floating pans are maintained under the direction of Caleb M. Saville, chief engineer, Board of Water Supply, Hartford, Conn. Results not published.

Gardiner, Me.

Evaporation for a Class A U. S. Weather Bureau Station, with circular pan 4 ft. in diameter and 8 in. deep, land exposed, supported on grillage, has been maintained at Gardiner, Me., during the months May to October, inclusive, beginning July, 1915, and continuing to date. The results are published monthly in Climatological Data, U. S. Weather Bureau.

Albany, N. Y.

A Class A land-exposed U. S. Weather Bureau standard evaporation pan is maintained at Voorheesville, N. Y., near Albany, N. Y., under the direction of Robert E. Horton. The record covers the summer months of the years 1918 to date. The pan is circular, 4 ft. in diameter and 8 in. deep, supported on grillage — readings taken by micrometer hook gage. Records of air and water surface temperatures, humidity, and wind velocity are also maintained. Records not published.

Discussion.

Mr. Caleb M. Saville. Does Mr. Horton say that his committee did not go into the matter of water losses? If I heard correctly, he said he did not. I wish that he would tell us something about water losses, because I know of no one who has made a more thorough or more complete study than Mr. Horton.

The one question that I should like to ask, perhaps, to start the discussion, but not to start discussion wholly on the mooted question of water supply, is this: Other things being equal, which is better, a water supply from ground covered with various trees, say with forty-year-old chestnut and mixed hardwoods, or one covered with scrub and sprouts after the timber has been cut off? I am thinking now of losses that come from evaporation. This I am sure is an interesting question to some of us, which has particularly come up in connection with the question of deforestation of our watersheds.

Mr. Horton. In regard to going into the matter of water losses: The committee has gone into it just to this extent, of making the simple subtraction of the annual or monthly run-off each month from the corresponding precipitation. We have not attempted to analyze this water loss. We have confined ourselves strictly, as a committee, to those two matters, — the collection of available records and the attempt to set forth, as we have done in the conclusions of the report, our ideas as to methods of obtaining and presenting run-off statistics which would give in the simplest manner possible reliable records, and records on a fairly uniform basis. I have not the slightest objection to going into the very interesting questions which Mr. Saville has propounded, but were I to undertake to do so, I should say that the only proper procedure would be to take off my coat and hammer away at it myself, as other members of the committee may possibly have different views.

I will state very briefly some things which possibly may cover the main points from my own point of view, without committing myself too definitely at this time. The questions which Mr. Saville has raised are some of the most perplexing questions, and they are questions to which no universal answer can be given by "yes" or "no." The conditions are different in different localities, and the answer will be different in different localities.

What I think is generally meant by water losses is all deductions from rainfall which occur through natural processes, especially those deductions in a water-tight drainage basin where all the rain that isn't lost goes down the stream sooner or later. Those deductions I have often classified as of three kinds. A considerable portion of rainfall over a forested area never reaches the ground, and at the same time my own experience indicates that in average showers the percentage may be 25 per cent., and averages 20 per cent. probably. It does not vary very much with the kind of trees, whether beeches, birches, maple, pine, or hemlocks. About 20 per cent. of the rain does not reach the ground at all. If the rain came in a very heavy storm every time it rained, there would be a much smaller percentage. But rain does not come that way in the Eastern states. It comes in average amounts of a third of an inch per rain-day.

The second point is evaporation from the soil. The evaporation from the soil is very much less — is very much less in a cropped field than a bare field, if the soil condition is the same. It is more in a cropped field than it is in a forest.

The third source of loss is from what has percolated through the soil and is drawn up in the roots of the plants and is passed out through transpiration through the leaves. That loss is relatively large. It amounts for a growing crop to perhaps ten or twelve or fourteen inches a year, but if there isn't that amount of water in the soil, a corn crop, for instance, will get along with a great deal less amount of water. So you see that the problem has many ramifications to which no general answer can be given.

Suppose the soil is of a good quality and available for agricultural uses. It was originally covered with a heavy forest of broad-leaved trees. Then, as the country was settled, the forest was cut away. Possibly there was more or less swamp which was drained. Then Mr. Water Works Man comes along and says to the municipality, " Now, let us buy this watershed, and we will control this ourselves." And, so far as the protection from pollution goes, it is a mighty good proposition, but usually there goes with it another feature which appeals strongly to the popular mind: " We will re-forest that area." But in most cases I am afraid that the answer to that should be " no." I may be wrong, and I may have to change my views on that point, and I wish to say here that I shall possibly change my view when more experimental data is at hand. We are trying to get some of these answers from some of these records that you are keeping and preparing.

But, just to take an illustration, which I have not cooked up in advance at all: In your original forested area you would have a loss out of 36 in. of rain of perhaps 9 in. by interception; you would have a loss by evaporation from the soil of perhaps 4 in., and you would have a loss by transpiration of perhaps 7 in. That would mean that there would be 20 in. of losses, leaving 16 in. out of your 36, or 16 in. of run-off, and that is the condition you would get there.

When the forest is cleared off and the land is under cultivation, with good farming land and productive growing crops like clover, corn, or potatoes, with rotation of grains, you would have an interception loss which would be greatly reduced, perhaps to 4 in. instead of 9. You would have evaporation from the soil considerably increased; probably 9 in. instead of 4. You would have a transpiration loss of probably 10 or 12 in., — say, 10 in., — so that you would have a total loss in that case of 23 in. as compared with the loss of 20 in. from the forested area.

But now take the other situation: If the water department purchased this drainage basin and bought out the farms, and the farmers moved away, and the land was allowed to run wild, to a certain extent, and simply grown up to wild grass and not put under forestation. Then you would have a still smaller interception, perhaps not more than 2 in. Perhaps you would have 12 in. of evaporation loss. Your transpiration loss would be cut way down to perhaps 5 or 6 in. So that probably you would have as small water losses, and very likely smaller, than from the original forest, and, so far as the conservation of water is concerned, the bare tract of land would yield more water than the forested area.

Mr. Saville. What I had particularly in mind was that in our Connecticut areas, and in Massachusetts also, we have been having very serious conditions, due to chestnut blight. Large areas that were once covered with chestnut trees have been cut off and laid bare after the blight struck them. The question has arisen as to whether it is better to cut all of the hardwoods as well, and then re-forest with other trees. It might be

tried on a strip of perhaps 50 or 60 acres. Then plant that, perhaps, with young trees of some quickly growing variety that will grow in five or six years. My thought was whether that growth was as well, or better perhaps, than the former growth that was there, so far as water supply is concerned.

Mr. H. N. Blunt.* Twenty years ago the watershed of each of our streams was very heavily wooded, but they are now being very rapidly cut off, and we are wondering what is going to happen, because there is no effort to re-forest, and all over the watershed brush has grown up, and instead of having a big umbrella, there is a scrub growth. We are much concerned with what will happen during the dry seasons. Mr. Horton did not touch on that feature of the problem, which may affect some of us, but it is certainly an interesting subject.

Mr. Horton. I have given a good deal of thought to that question. The question seems to me this, essentially: "What is the difference between the heavy, dense forest and the scrub forest and woods in the forest by which it may be replaced after it is burned over or cut?" I am very sorry that I cannot help you definitely, because the data are so meager that it is only by careful study of the matter of transpiration of different kinds of trees that a judgment can be formed. It is possible by careful study of existing results that reliable judgment might be formed, but I should hate to give an off-hand judgment of it. There are some places in Switzerland that have been keeping records in this regard, but there is no station in the United States where this information has been collected and kept. This question of yours involves especially the relative transpiration losses for small and large trees. I would say that as far as I can go would be this: Young plants generally transpire water more readily and rapidly in proportion to the weight of dry matter produced in the plant than does a maturer or older plant. On the other hand, the transpiring surface is much smaller. Just how that balance will work, I am unable to say.

* Superintendent Water Company, Palmerton, Pa.

REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

The Joint Committee of the American and New England Water Works Associations, on Standard Specifications for Water Meters, submits its final report, accompanied by a draft of Standard Specifications for Cold-Water Meters, Disc Type, which it recommends for adoption; a statement of the information which should be furnished to meter manufacturers when requesting bids under the proposed specifications; a description of the equipment necessary to test meters for compliance with the registration and capacity requirements of the specifications; and a statement of tests recommended.

Appointment, Organization, and Meetings of Committee. The formation of a committee on meter specifications was suggested by Mr. R. J. Thomas, who presented a brief paper to the convention of the New England Water Works Association at Portland, Me., in 1916, calling attention to the desirability of uniform standard specifications for meters. Following the presentation of that paper it was voted that a committee of the New England Water Works Association be appointed.

In 1919, upon the representation of members of the New England Association's committee to the American Association, the latter voted to appoint a similar committee, which was done forthwith.

The first actual meeting of the Joint Committee, or of either of the committees appointed by the associations, was held on March 9 and 10, 1920. Prior to that time such progress as had been made was accomplished by correspondence.

It was immediately decided to organize as a Joint Committee, and to make a single report to both associations. The committee organized with Charles W. Sherman as chairman and Seth M. Van Loan as secretary.

At the conclusion of the meeting of March 9 and 10, 1920, a subcommittee consisting of Messrs. Saville, Brush, Van Loan, and McMurry, was appointed, to give further consideration to points raised in the main committee, to carry out certain experimental work, and to obtain some further information from the manufacturers, and to report back to the Joint Committee at a later date.

The second and concluding meeting of the Joint Committee was held February 8 and 9, 1921, at which time the draft of the specifications was tentatively adopted and the form of the report considered. The final work of the committee has been accomplished by correspondence.

Preliminary Work of New England Water Works Association Committee. Correspondence between the members of the New England

Association's committee began soon after the original appointment in 1916, but before anything of significance had been accomplished the United States entered the World War and it became impracticable for the members of the committee to devote any material amount of time to committee work. Late in 1917, however, the Department of Water Supply, Gas, and Electricity of New York City prepared a tentative draft of specifications, under the direction of Mr. W. W. Brush, a member of the committee. After further correspondence between the members of the committee it was planned to print these tentative specifications as a basis for discussion, and submit them to the 1918 convention of the New England Water Works Association, as a progress report; but before this was done information from the manufacturers indicated that certain points in the tentative draft should be discussed with the manufacturers before submitting them to any convention, and the draft was therefore not circulated.

Draft of Specifications Prepared by Meter Manufacturers. During 1918 and 1919 the manufacturers of water meters held a series of conferences under the auspices of the Meter Manufacturers' Exchange, — but to which manufacturers not members of that exchange were invited, — at which they discussed the subject of specifications and finally prepared a draft of standard specifications acceptable to all of them. These conferences were held in New York City, and during the latter part of the time were attended by Mr. W. W. Brush, as representative of the New England Association's committee. They concluded in February, 1920, when a draft of standard specifications acceptable to the manufacturers was completed.

The Meter Manufacturers' Exchange includes the Buffalo Meter Company, Hersey Manufacturing Company, Neptune Meter Company, Pittsburgh Meter Company, Thomson Meter Company, Union Water Meter Company, and Worthington Pump and Machinery Company. Other manufacturers not members of the Exchange are Badger Meter Company, Gamon Meter Company, and National Meter Company. It is the understanding of the committee that all of the manufacturers were either represented at the conferences or subsequently assented to the action taken at those meetings.

The specifications thus drafted and submitted to the Joint Committee of the Water Works Associations covered both the disc and current types of meter.

Work of the Joint Committee. Following receipt from the manufacturers of their draft on a standard specification, the Joint Committee met on March 9 and 10, 1920, as above noted, and proceeded to analyze and discuss the specifications submitted by the manufacturers.

It was at once decided to limit the committee's work to specifications for disc meters, for several reasons, the most potent being that substantially all of the meters likely to be bought under competitive bidding

belong to this class. It was also felt that if standard specifications for disc meters were adopted, after they had been in use a number of years the experience with them would indicate more clearly than can now be anticipated, the kind of specifications which should be prepared to cover other classes of meters.

During the year 1920 the subcommittee continued the investigation of various questions left unsettled by the Joint Committee, and finally reported back to the committee a revised draft of specifications, a statement of information which should be furnished to bidders in asking for bids under the specifications, a description of the tests necessary to determine whether meters complied with the specifications, and a list of the minimum equipment with which such tests could be made.

At the final meeting of the committee, on February 8 and 9, 1921, the material submitted by the subcommittee was discussed in detail and amended in some minor particulars, and then referred back to the subcommittee for submission to the manufacturers. Further slight modifications have been made as a result of comments by manufacturers, and the material as thus finally revised has been accepted by the committee, through correspondence.

Acknowledgment. In presenting the proposed specifications to the two associations for their consideration, the Joint Committee wishes particularly to acknowledge its indebtedness to the meter manufacturers, who showed throughout an earnest desire to coöperate and to comply with all reasonable requirements, and particularly to standardize details of construction with the object of making meters of various makes interchangeable in service, without rearrangement of connections.

Respectfully submitted,

For the Joint Committee,

CHARLES W. SHERMAN, *Chairman.*

William W. Brush, *Chairman.*
Charles W. Sherman, Henry V. Macksey,
A. W. F. Brown, James A. McMurry,
R. J. Thomas, John H. Walsh,
N. E. W. W. Ass'n Committee.

Caleb M. Saville, *Chairman.*
Dow R. Gwinn,
R. J. Thomas,
Seth M. Van Loan,
Am. W. W. Ass'n Committee.

APRIL 7, 1921.

STANDARD SPECIFICATIONS FOR COLD-WATER METERS, DISC TYPE.

Cases. All meters shall have an outer case with a separate inner chamber in which the disc operates. The outer case for all 2-in. and smaller meters shall be of bronze composition. Cast-iron frost bottoms may be provided. The outer case for meters larger than 2 in. shall be of bronze composition or of cast iron protected by a non-corrosive treatment.

All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters larger than 1 in. shall be designed for easy removal of all interior parts, without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either " round " or " straight " reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial, and the minimum capacity of the register when indicating cubic feet, shall be as follows:

Size. Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
$\frac{5}{8}$	1	100 000
$\frac{3}{4}$	10	1 000 000
1	10	1 000 000
$1\frac{1}{2}$	10	1 000 000
2	10	10 000 000
3	10	10 000 000
4	100	100 000 000
6	100	100 000 000

All dials, including the initial dial, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box to prevent dirt from accumulating on the glass. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-

escape hole $\frac{1}{8}$ in. in diameter, placed so that the change gear or registering mechanism cannot be tampered with.

Connections. $\frac{5}{8}$-in., $\frac{3}{4}$-in. and 1-in. Sizes. Spuds shall be threaded $\frac{3}{4}$, 1, and $1\frac{1}{4}$ in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand within one thread of through the gage.

Over-all lengths of meters, face to face of spuds, shall be —

$\frac{5}{8}$-in. — $7\frac{1}{2}$ in.
$\frac{3}{4}$-in. — 9 in.
1-in. — $10\frac{3}{4}$ in.

Couplings shall be made of bronze composition. Nuts shall be tapped $\frac{3}{4}$ in., 1 in. and $1\frac{1}{4}$ in. respectively, straight thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be backed into the nuts by hand; i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $\frac{1}{2}$, $\frac{3}{4}$ and 1 in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand, flush with the face of the gage.

Over-all lengths of tailpieces shall be —

$\frac{5}{8}$-in. — $2\frac{3}{8}$ in.
$\frac{3}{4}$-in. — $2\frac{1}{2}$ in.
1-in. — $2\frac{5}{8}$ in.

Connections. $1\frac{1}{2}$ in. and 2 in. Sizes. Spuds shall be tapped $1\frac{1}{2}$ and 2 in. respectively, female thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be screwed on by hand up to the notch on the plug.

Over-all lengths of meters, face to face of spuds, shall be —

$1\frac{1}{2}$-in. — $12\frac{5}{8}$ in.
2-in. — $15\frac{1}{4}$ in.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 in. and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size, and so tapped that Briggs Standard pipe thread plug gages may be backed into the nuts by hand; i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ in. and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs Standard pipe thread ring gages may be screwed on by hand flush with the face of the gage; 2 by $1\frac{1}{2}$ in. and $2\frac{1}{2}$ by 2 in. standard pipe size malleable-iron bushings are to be furnished with $1\frac{1}{2}$ in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand, and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be —

$1\frac{1}{2}$-in. — $2\frac{7}{8}$ in.
2-in. — 3 in.

Connections. 3-in., 4-in. and 6-in. Sizes. Spuds shall be flanged, faced and drilled. Companion flanges shall be of cast iron, faced, drilled and tapped. All dimensions, drilling and tapping, shall conform exactly to American standard of January 1, 1914.

Over-all lengths of meters, face to face of flanges, shall be —

3-in. — 24 in.
4-in. — 29 in.
6-in. — $36\frac{1}{2}$ in.

Seal Wire Holes. $\frac{5}{8}$-in., $\frac{3}{4}$-in., 1-in., $1\frac{1}{2}$-in. and 2-in. meters shall have register box screws and coupling nuts drilled for seal wire holes. Meters larger than 2 in. in size shall have register box screws drilled for seal wire holes. All seal wire holes shall not be less than $\frac{3}{32}$ in. in diameter.

Measuring Chambers. The measuring chamber for all meters shall be made of bronze composition and shall not be cast as part of the outer casing. It shall be machined with great care and secured in position in the outer casing so that any slight distortion of the casing which might take place under 150-lb. working pressure will not affect the sensitiveness of the meter.

Discs. Disc pistons shall be made of vulcanized rubber, and shall be fitted accurately but freely in their chambers. Vulcanized rubber pistons shall have a metal reinforcement or a thrust roller.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed, and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers except when self-strained by means of an annular space between the measuring chamber and the external case. Strainers shall be made of non-ferrous materials and shall fit tightly against the wall of the casing. They shall have an effective straining area as large as practicable and at least double that of the inlet.

Registration. The registration on the meter dial shall indicate the quantity recorded to be not less than 98 per cent. nor more than 102 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified herein under "normal test-flow limits." There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test-flow."

Size. Inches.	Normal Test-Flow Limits. Gallons per Minute.	Minimum Test-Flow. Gallons per Minute.
$\frac{5}{8}$	1 to 20	$\frac{1}{4}$
$\frac{3}{4}$	2 to 34	$\frac{1}{2}$
1	3 to 53	$\frac{3}{4}$
$1\frac{1}{2}$	5 to 100	$1\frac{1}{2}$
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1 000	12

Capacity. New meters shall show a loss of head not exceeding 25 lb. per square inch, when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
$\frac{5}{8}$	20
$\frac{3}{4}$	34
1	53
$1\frac{1}{2}$	100
2	160
3	315
4	500
6	1 000

Pressure Test. Disc meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in., without leakage or damage to any part.

Workmanship and Material. Disc meters shall be guaranteed against defects in materials and workmanship, for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Information to be Furnished to Meter Manufacturers when Requested to submit Bids on Disc Meters.

1. Meters shall conform to the Standard Specifications for Cold-Water Meters, Disc Type, adopted by the American and New England Water Works Associations.

2. The manufacturer shall state in his bid the type of meter he proposes to furnish, as listed in his catalogue. The actual capacity of each size of meter called for is to be given graphically from 0 lb. up to 25 lb. loss of pressure. If this capacity be stated in the manufacturer's catalogue, reference may be made thereto.

3. No bid will be considered on meters of a design which has not been listed for at least one year in the catalogue regularly issued by the manufacturer.

4. The method of testing meters shall conform to that recommended by the Committee on Standard Specifications for Water Meters.

5. (*a*)* The meters are to be accepted on a certificate furnished by the manufacturer, that the meters have met the requirements of the Standard Specifications for Water Meters, as adopted by the American and New England Water Works Associations.

(*b*)* The meters will be tested by the purchaser to determine whether they do or do not comply with the Standard Specifications for Water Meters adopted by the American and New England Water Works Associations.

6. Registers shall be $\left\{\begin{matrix}\text{round}\\ \text{straight}\end{matrix}\right\}$ reading, and shall record in $\left\{\begin{matrix}\text{cubic feet}\\ \text{gallons.}\end{matrix}\right\}$

Equipment Necessary to Test Meters for Compliance with Registration and Capacity Requirements, as set forth in the Standard Specifications for Water Meters.

The standard specifications require that meters shall accurately record the flow within certain limits and shall pass a given quantity of water with a maximum loss of pressure. Suitable equipment to make accurate tests must be available before the purchaser should make complaint of meters not complying with the specifications.

The minimum test equipment required for registration and capacity is as follows:

1. A quick-acting valve on the supply pipe through the use of which the flow can be started and stopped without appreciable loss of time.

2. A valve on the outlet side of the meter which can be used to establish the rate of flow desired.

3. Pressure gages connected on both the inlet and outlet of the meter to show whether any material change in pressure occurs during the period of test which would affect the rate of flow. (The outlet pipe is to have sufficient head on it so that the meter will always have pressure on its outlet end and preferably not less than 5 lb. per sq. in.)

4. A measuring device which may be either of the volumetric or weighing type. Whichever is used, the accuracy of determination of the volume or weight of water discharged into the measuring device must be such as to bring the limit of error within one tenth of 1 per cent. (The volume of water passed must be sufficient to cause at least one or more revolutions of the pointer on the initial dial, except for tests at "minimum test-flow" rate. For the latter test, the amount passed shall not be less than one cubic foot.)

It is desirable to have available for testing meters a test table and appurtenances which are manufactured by several concerns. Such an

* *Note.* Sentence (*a*) is to be used where the purchaser does not have suitable equipment to test the meters. If he has such equipment then sentence (*b*) is to be used.

outfit would include the equipment enumerated in the preceding four paragraphs.

For the capacity tests, it is necessary to add to the above equipment, 2 piezometer rings which must be of exactly the same diameter. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not less than four holes shall be provided, drilled in pairs and on diameters at right angles to one another. The inlet piezometer ring shall be set close to the meter, and shall be at a distance of not less than eight diameters from the nearest upstream stop-cock or fitting in the supply pipe. The outlet piezometer ring shall be placed at a distance of not less than 8 nor more than 10 diameters from the outlet of the meter. The diameter of the piezometer rings and inlet and outlet pipes shall be the same as the size of the meter to be tested. The piezometer rings are to be connected by either rubber or metal tubing to a mercury U-tube. To this U-tube is to be attached an accurate adjustable scale for measuring the differences between the inlet and outlet pressures. Provision is to be made for the complete removal of air from the tubing connected with the U-tube, and the U-tube and the tubing connected therewith is to be so placed that the air will rise to the outlets. Where relatively high flows are to be recorded, it is necessary to read both sides of the mercury column to compensate, as far as practicable, for irregularities in the diameter of the glass U-tube, and such readings are to be made as nearly simultaneously as possible to avoid errors due to fluctuations.

Tests of Meters Recommended.

The tests to be made on the meter are divided into two classes:

1. Capacity test.
2. Registration test.

Capacity tests are those which test the design of the meter rather than the workmanship thereof. When a meter of a given make has once been tested for capacity, it should not be necessary to again test this type of meter unless a change has been made in its design.

The registration tests should be made on each meter, as the results are affected by workmanship and assembly of individual meters. There is no certainty that, because one meter of a given make comes within certain limits of accuracy, another meter of the same make turned out by the factory on the same day will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and purchaser in making registration tests. Where the purchaser does not have the necessary equipment to test the meters, there should be furnished by the manufacturer a certificate that each meter has been tested for accuracy of registration and complies with the standard specifications in this respect, and that the type of meter furnished has complied with the capacity requirements.

The registration tests recommended are as follows:

All meters should be tested for accuracy of registration within and as near as practicable to the low and high rates given under "Normal Test-Flow Limits."

A test at the "Minimum Test-Flow" should be made on as many as possible, and not less than 5 per cent. of the meters. If the results obtained from testing 5 per cent. of the meters show that any meter does not comply with the low-flow requirement, additional meters should be tested to the extent deemed necessary to make certain that the other meters do comply therewith.

The pressure test should be made on each size of meter furnished of a particular type. This pressure is to be 150 lb. per sq. in., and the pressure may be furnished through the use of a hand pump or such other method as may be available. Before the meter has been tested by static pressure, and also after it has been so tested, it should be tested for accuracy to see whether the meter has been so distorted as to affect registration. It is considered unnecessary to make a pressure test of each size of meter of a given type more than once if satisfactory results are obtained.

If it be possible to give a working-pressure test under 150 lb. per sq. in., then such a test should be applied rather than a static-pressure test.

JAMES P. BACON — PROF. WILLIAM T. SEDGWICK.

February 9, 1921.

The President. It is my sad duty to call to the attention of the meeting two great losses which we have suffered since our last meeting.

Our well-known stenographer and friend, Mr. James P. Bacon, has passed away. Mr. Bacon has reported the meetings of this Association practically from its beginning, and was well known to a very large number of our members and much beloved by every one who knew him. Although Mr. Bacon was not a member of the Association, I feel that the Association has suffered as much of a loss as it would in the loss of a member. I know his interest was with us, and he was always present when he was able to come.

We have also lost a past president and honorary member, Prof. William T. Sedgwick, and I am going to ask Professor Whipple to say a few words of appreciation of Professor Sedgwick.

Professor Whipple spoke feelingly of Professor Sedgwick's life and work, closing as follows:

This is not the time or the place to tell the whole story of Professor Sedgwick's life. We merely wish to give due honor to his memory and to interrupt our proceedings in order that we may think of him in sweet remembrance.

The President. May I ask that everyone stand for a moment in silent tribute to the memory of Mr. Bacon and Professor Sedgwick.

[Everybody rises and stands in silence.]

WILLIAM THOMPSON SEDGWICK.

A complete appreciation of the life of William Thompson Sedgwick will never be written except in the hearts of his hundreds of friends. The important milestones in his life are the following:

1855, December 29, born a son of William and Anne Thompson Sedgwick, at West Hartford, Conn.

1877, graduated from the Sheffield Scientific School, Yale University, Ph.B. in biology.

1878, instructor in physiological chemistry at Yale.

1881, graduated from Johns Hopkins University, Ph.D. in biology.

1879–83, fellow, instructor, and associate in biology.

1881, December 29, married Mary Katrine Rice, of New Haven, Conn.

1883, assistant professor of biology, Massachusetts Institute of Technology.

1885, associate professor of biology, M. I. T.

WILLIAM THOMPSON SEDGWICK

1886, joint author of "General Biology."

1888–96, biologist of the Massachusetts State Board of Health.

1891–1921, professor of biology and public health, and director of the Sanitary Research Laboratory, M. I. T.

1897–1921, curator of the Lowell Institute.

1899–1921, trustee of Simmons College.

1900, president of the Society of American Bacteriologists.

1901, president of the American Society of Naturalists.

1902, published "Sanitary Science and Public Health."

1902–1921, member of the Advisory Board of the Hygienic Laboratory of the U. S. Public Health Service.

1906, published, with Theodore Hough, "The Human Mechanism."

1913–1921, chairman of the Administrative Board of the School of Public Health of Harvard University and the Institute of Technology.

1914–1921, member of the Public Health Council of the Massachusetts Department of Health.

1915, president of the American Public Health Association.

1917, published, with H. W. Tyler, "A Short History of Science."

1920, exchange professor at the Universities of Leeds and Cambridge, England, and "ambassador of health" from the American Public Health Association to the Allied Conference at Brussels.

1920, delivered address at the one hundredth anniversary of the Medical School of the University of Cincinnati, and received degree of LL.D.

1921, January 25, died at Boston.

In the above outline of a career full of honor, there is no record of Professor Sedgwick's connection with this Association, and little of his work in the field of water supply.

There have appeared many eulogies describing his various activities as writer and teacher of biological science, as interpreter of the laws of health, as epidemiologist, as wise counselor of state and university, as eloquent lecturer on sanitary science, and as citizen and patriot, but it seems fitting to record here the Association's appreciation of his work in its own field.

Sedgwick was a student at Yale while Pasteur was doing much of his pioneer work in bacteriology, and when Robert Koch discovered the bacillus of anthrax. He was studying at Johns Hopkins University when Eberth discovered the typhoid fever germ, and began his work at the Institute of Technology in 1883, the same year that Koch discovered the germ of cholera. Hitherto his intention had been to become a physician, but with the prescience which was characteristic of his later life, Sedgwick now abandoned this intention and devoted his life to applied biology, thus beginning his professional work when even so eminent a sanitary chemist as William Ripley Nichols was skeptical about the relations between bacteria and water-borne disease.

In the years before 1887, the Journal of the Association contained practically no papers relating to water as such, to methods for determining its quality, or to its relation with water-borne disease. In these regards,

the early years of the Association were years of growth; the year 1887–88 was a year of fruition. In this Sedgwick played an important part. At the meeting held at Young's Hotel on March 12, 1888, he read a paper entitled, "The Biological Examination of Water." This was discussed by E. K. Dunham, Desmond FitzGerald, F. P. Stearns, Samuel W. Abbot, and A. F. Noyes. It was the first presentation to the Association of the conclusions of the new science of bacteriology, the application of which to the art of water supply was stimulated by the Massachusetts Inland Waters Act of 1886, and the work of Walcott, Mills, Sedgwick, Drown, Stearns, and others, serving as officers of the State Board of Health and the Lawrence Experiment Station. Professor Sedgwick was consulting biologist of the Board, and with his colleagues directed the work at Lawrence. The station work was under the immediate direction of Allen Hazen, who was succeeded by George W. Fuller, and he in turn by the present director, Harry W. Clark. It is unnecessary to describe the work of the Lawrence Experiment Station in the fields of water purification and sewage disposal. It stands for itself. The station has been the birthplace of many scientific discoveries, and the nursery of some of the leading sanitary engineers of the country, and both discoverers and engineers owe much of their success to their consulting biologist, — to his knowledge of men and things, and particularly to his ability to emphasize the important, a quality which he possessed to a remarkable degree.

In 1890, an epidemic of typhoid swept down the valley of the Merrimack River, and Sedgwick was detailed to study it. While not possessing the mathematical mind, Sedgwick understood the dramatic use of statistics as did few of his time, and so presented the facts connecting the typhoid fever of the valley cities with the sewage of their respective upstream neighbors, that his conclusions were unassailable. This work led to the Lawrence water filters, designed by Hiram F. Mills, C.E. This, the first scientifically designed filter in America, is, with its additions, although outgrown in size and basis of design, still protecting the citizens of Lawrence against an epidemic like that of 1890.

It was in the field of epidemiology that Sedgwick was at his best as a workman. Not only did he determine the history of several notable epidemics, particularly of water-borne typhoid fever, but, more than that, developed new methods of study which have been used by his followers with success.

Professor Sedgwick joined the New England Water Works Association in 1890, became an honorary member in 1904, and was elected president in 1906. His term of office is remembered as among the most fruitful years of the Association. After the presentation of his first paper in the second volume of the JOURNAL, the following papers and discussions appeared:

Volume IV, "Biological Water Analysis."

Volume V, "Surface Water for Drinking Purposes."

Volume VII, "Sand Filtration."

Volume X, "Sanitary Condition of the Water Supply of Burlington, Vt."

Volume XI, "Organisms Which Cause Unpleasant Odors and Tastes in Water Supplies."

Volume XX, "Responsibility for the Causation of Typhoid Fever."

Volume XX, "Protection of Water Supplies from Pollution by Railroads, with Special Reference to the Supply of Seattle, Wash."

Volume XXV, "Has the Time Come for Municipal Double Service?"

Volume XXV, "Notes on Typhoid Fever at Washington, D. C."

Volume XXX, "Water Supply Sanitation in the Nineteenth Century and in the Twentieth."

Not only was Professor Sedgwick memorable because of his personal contributions to the papers and discussions before this Association, but as a teacher of sanitary engineers. Many of these have reflected the training received at his hands in the literary work of the Association. One has only to recall the names of Allen Hazen, George W. Fuller, Joseph W. Ellms, Stephen DeM. Gage, F. S. Hollis, D. D. Jackson, William S. Johnson, Morris Knowles, M. O. Leighton, Elbert E. Lochridge, Earnest C. Levy, Charles P. Moat, Horatio N. Parker, Gilbert H. Pratt, Charles W. Sherman, Carol T. Storey, W. Lyman Underwood, C.-E. A. Winslow, and others, to realize the influence of his teaching upon the art of water supply as developed by the work of this Association.

After 1914, Professor Sedgwick continued his work for the state as a member of the Committee on Sanitary Engineering of the Public Health Council of the State Department of Public Health.

It was the custom at the Department of Biology and Public Health at the Institute to hold weekly conferences of teachers and students, presided over by the "Chief." The subjects were live and varied, — a new water-purification process, a typhoid epidemic, why so many babies die, public health work in China, the work of the Red Cross expedition to Serbia, why Dr. Blank failed in the West, and others of human and cosmopolitan interest.

In recent years these conferences have included the students of the public health school, coming from the principal countries of the world. At these conferences, criticisms by the "Chief" were candid and personal, often severe, but also kindly. He conquered bumptiousness and bad manners by urbanity and courtesy. Many a rough diamond began its transformation into a gem at these profitable meetings.

His last address before the Association was delivered on September 11, 1918, on the timely subject, "From Peace to War, from War to Victory, from Victory to Just Judgment." This address was delivered at a well-attended meeting, and was heard with sympathetic attention. This address revealed the ripened man, the springs of his character, also his

uncomprising support of stern justice for the worshipers of the tribal God of the Teutons and their Kaiser, and his faith in the Christian ideal of service.

Those who knew Professor Sedgwick as fellow-member, teacher, counselor, leader or friend, will long treasure the influence which he radiated from his lovable and inspiring personality.

His last years and hours indicated his courage and spirit of service. Although suffering for several years from an affection which limited his activities and ultimately caused his death, he unremittingly promoted the welfare of the country and the expeditionary forces during the Great War in many important ways, not the least of which were the emergency training of laboratory workers to take the place of those who had entered the service of the Government, and the work for the refugee children of France. On the last evening of his life, he spoke at a meeting in the interest of education.

With this patriotic work, and in fact with all of the work of his life, Mrs. Sedgwick was closely associated. In the hearts of Professor Sedgwick's students, her personality will always be associated with his.

William Thompson Sedgwick lived honestly and unreservedly. He made no distinction between the sacred and the profane. With him all life was sacred. The God of his heart was the God of his country and the God which his study of science revealed. With him, a beloved member of this Association, a scholar, an interpreter of science, a worthy public servant, and a Christian gentleman has entered the larger life.

ROBERT SPURR WESTON.
GEORGE CHANDLER WHIPPLE.

CHARLES WILLARD YOUNG.

CHARLES W. YOUNG passed away suddenly at his summer home in St. Stephen, N. B., on the St. Croix River, September 21, 1920. He was born in Calais, Me., November 11, 1858, the son of Benjamin and Rhoda (Stevens) Young.

Mr. Young became a member of this Association in 1915 and while not active took much interest in its progress.

When a young man he became a partner with his father in the lumber firm of Benjamin Young & Son, who carried on extensive operations in Nova Scotia for several years.

Mr. Young was for thirty years president and a large owner of the St. Croix Soap Manufacturing Company and held a large interest in the Calais & St. Stephen Street Railway, and many other enterprises in this section and mining interests in the southwest.

In recent years he became interested in the Warren Brothers Corporation, in the construction of improved roads, and has been an important factor in the great success of their work.

About eight years ago he purchased and fitted up a beautiful home in Winchester, Mass.

His activities in water supply were in the incorporating of the Barnstable Water Company, covering the towns of Barnstable, and Yarmouth on Cape Cod, and has been president of this company since its start in 1912. He was for a time president of the Norton Water Company.

Recently he established in Boston the managing firm of C. W. Young & Sons, in which he was joined by his two sons, Frederic and Kenneth, and they took over the property of the Mercer County Light, Heat and Power Company, also the Pittsburg District Electric Company, and the Barnstable Water Company.

Mr. Young was an enthusiastic curler and was for several years president of the St. Stephen Curling Club; also of the Golf Club. He was a member of the Calais Universalist Church, and the Boston Art Club.

Mr. Young was one of the most lovable of men, a genial companion and an honorable opponent; a man of strong will and great ability, which he exercised freely in the interests of his wide circle of friends. The Association, the community, and the state lose a strong agent for the best in many of the most important of human interests.

He is survived by his wife, two sons, and three daughters, — Mrs. Vera Wadsworth, of Cleveland, Ohio; Mrs. Rhoda Le Royer, of New York, and Mrs. Georgia Farnsworth, of Boston.

Henry A. Symonds.
Hervey A. Hanscom.

RICHARD L. TARR.

Richard L. Tarr, a member of this Association, died October 12, 1920, after more than eighteen months' illness. He was a native of Gloucester, Mass., where he was born March 1, 1880, and was the son of James H. and Elizabeth G. (Burnham) Tarr. He was a descendant of Richard Tarr, the original settler of the name on Cape Ann. He has been connected with the Gloucester Water Department for about twenty years, being first employed in the survey of Haskell's Reservoir in 1901, and was appointed a foreman in 1904, holding the position until the time of his death.

He was a man who was universally liked and esteemed, always having a pleasant greeting for his friends and acquaintances. He is survived by his mother and three brothers — Alfred C., Hardy B., and Philip V. Tarr — and two sisters, Misses Esther and Priscilla Tarr.

Mr. Tarr was elected a member of the New England Water Works Association September 14, 1911.

John W. Moran.
James W. Blackmer.

EDWARD L. HATCH.

Mr. Edward L. Hatch was born in Stamford, Conn., October 16, 1878. He received his early schooling through private tutors and later spent two years at Lakewood.

His first business training was with the Stamford Trust Co., where he remained for several years. In 1905 he became connected with the Stamford Water Company as executive clerk and assistant treasurer in general charge of the office. In November, 1906, he was made general manager, and in December, 1909, was elected a director. He remained director, general manager and assistant treasurer to the time of his death on November 4, 1920.

Mr. Hatch was married on August 4, 1915, to Emma Hurlbut, of Riverside, Conn.

He was very fond of trapshooting and fishing and was an ardent hunter, having at various times visited the West, Canada, Mexico, and Maine on hunting expeditions.

He was a director of the Citizens Savings Bank and the Stamford Yacht Club, and president of the Suburban Club.

He was a member of the Presbyterian Church in Stamford.

Mr. Hatch was very highly regarded in the community on account of his ability, his fine personality, and his courtesy to all. His friends will long mourn his loss.

He died at his home at Shippan Point, of pneumonia, following influenza, after a gallant battle lasting about six weeks.

Mr. Hatch was forty-two years old when he died, and is survived by his wife and twin sons, four years old.

to send their superintendents, chief engineers, and superintendents of pipe laying to the foundries once in a while, to spend a day or two in going over the process of pipe making; and that on the other hand it would be money well spent for the foundries to send some of the heads of departments of production to the cities, or companies for whom they are making pipe, to see some of the problems they are up against. Result, a much better mutual understanding of one another's difficulties and a better spirit of "*give and take*"; for, taken as a whole, there are no fairer-minded folks than the consumer and producer of cast-iron pipe, only each cannot get the other's viewpoint unless they see for themselves.

Present-day practice for making cast-iron pipe from its natural to its finished state is: Ore in the ground; ore at the smelter or furnace; pig from the furnace; pig in the cupola or remelt furnace; molten iron in the ladle from cupola; molten iron cast from ladle to mold; cast pipe taken from mold to cleaning point; pipe after cleaning to reheating oven; pipe from reheating oven to coating tank; frem coating tank to weighing point; from weighing point to hydraulic test; from test to store yard or on vehicle for shipment to customer; from store yard to vehicle and thence to consumer; placed in the ground and put in service. And there you are, back to Mother Earth again.

The buildings, machinery, fixtures, tools, and equipment for making pipe are: Main foundry building; cupola or remelting furnace; cranes for handling materials and pipe; molding machines, either hand tools or a strictly mechanical device; core-making machinery; flasks for molds; core bars for cores; chills, flasks, bottom or pouring plates; core irons for socket cores; cups and centers, for forming beads; body patterns; head patterns; former box, for forming socket cores; bead rings, for forming part of beads; former, for forming gate and shrink heads; machinery for furnishing power for handling machinery; machinery for furnishing air for cupola; ovens for molds, cores, socket cores and bead cores, and for reheating before coating; core-making machines; skids for placing pipe after casting; coating apparatus; cutting-off machines; weighing machines; testing machines; cleaning tools and machinery; transfer cars for various purposes.

The production of cast-iron pipe in this country with all foundries running their full capacity amounts to between 700 000 and 800 000 tons per annum, and of this tonnage, possibly one third are pipe made bells up and two thirds bells down; eventually it is possible they will all be cast bells down.

Now let us take a personally conducted trip through the foundry and follow a day's work of the 12-in. pipe which we have recently purchased.

After we have satisfied ourselves that the office has entered the order as per our instructions, and that they have issued the manufacturing order in accordance therewith, our first stop is at the point where the molds are made; here we find heaps of sand tempered to the proper consistency so

that it will, when packed around the pattern in the flask, remain where it is put when the pattern is withdrawn, and yet be open or porous enough to allow the gases to escape, yet not the iron; we also see a number of heavy iron flasks perforated so that gases generated by the heat of the iron, or gases in the iron itself, can escape. We next see a flask placed in position for receiving the molding sand; and the patterns, which are of the form of the pipe to be produced, are lowered in the flask. If there is a pipe-molding machine we find the flask under this machine; if they are to be rammed by hand, the ramming gang take up their positions surrounding the flask and pattern with their ramming tools; next the molding sand referred to before is shoveled in the space between flask and pattern, and the machine or the ramming gang with hand-ramming tools starts packing the sand and ramming it between the pattern and flask, care being exercised in keeping rate of packing or ramming uniform, so that the mold when completed will remain in place after the pattern is withdrawn, nor allow the pressure of the iron when being cast to force it out of position. After the pattern is withdrawn, the completed mold is placed for the blacker to apply the blacking coat, which is usually a mixture of carbon, molasses and water of proper consistency; before applying the blacking the markings which you specified to be cast on the pipe are put in the mold by pressing the sand back with metal letters and figures. Next we notice that they are making a core to be placed on the bottom plate, which will form the interior of the bell or socket, and another which will form the bead.

These cores are made by taking the machined forms previously mentioned in the list of appliances, and placing therein material which when dried will retain the same form as the equipment in which made, and be strong enough to withstand the shock of the molten iron in pouring.

In the case of the socket core this material usually consists of a strong, moist, gravelly mixture tamped in place with a ramming tool or pressed in the form by hydraulic machinery, after which it is given a coat of blacking and placed to dry.

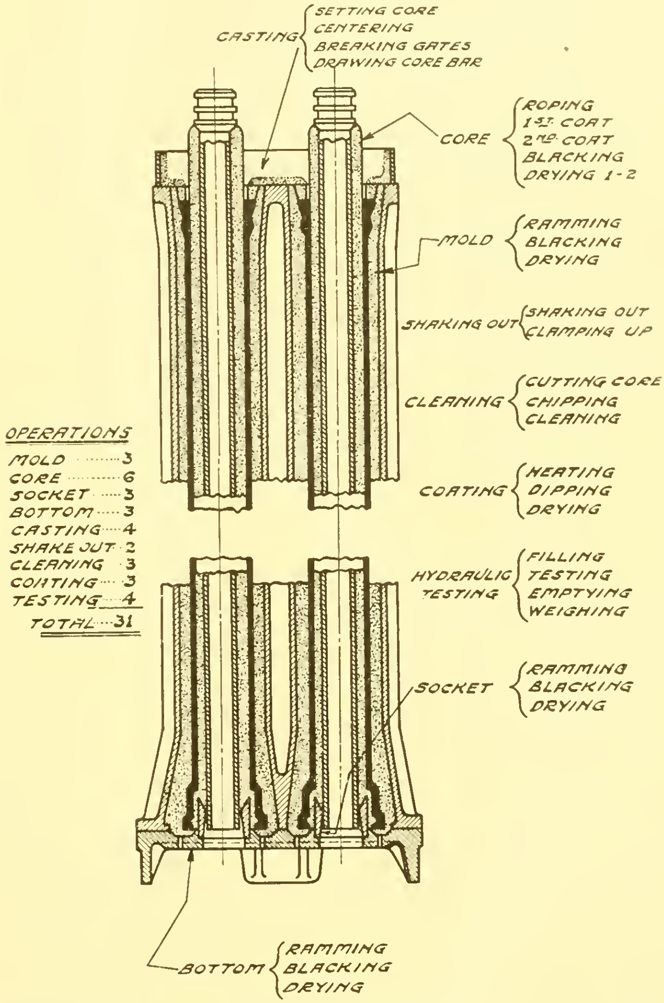
In the case of the bead core the material is usually a strong mud of similar consistency to that used for forming the main core; sometimes this core is coated with blacking but more often is not, as being made up and dried in a machined form it presents a sufficiently smooth surface, and blacking would simply be an extra refinement.

Next we see the completed mold placed at some point where heat is applied to the interior until it has had the moisture eliminated; ordinarily this is done over night, though in some foundries they use a higher temperature, and pour the pipe sooner, which is what is called "skin drying" the mold. The next step is to the part of the foundry where the cores are being made; the cores are formed on round iron bars, made hollow and perforated the same as the flasks, to provide for the escape of gases. These bars are placed on a table on bearings, where they are revolved, usually by mechanical means. There are under present practice five substances

used on these bars before the mud of the first coat is put on; these are, salt, hay or straw rope, Indiana long grass rope, paper and "skilley"; the term "skilley" being used to designate some substance that will ignite and burn easily when dry, and may be small particles of straw, grass, or wood cut fiber-fashion, like "excelsior," only shorter fibers, and mixed with a weak mud to hold the particles together, and to adhere to the core bar. After one of the above-mentioned materials is put on, a coating of coarse mud is put on, and the rough core placed in an oven to dry. After drying it is again put on the table, and the last, or finishing coat, which is a finer quality of mud, is put on, and on this finish coat is applied a coat of blacking somewhat like that applied to the molds, after which it is put in an oven and thoroughly dried.

We now return to a part of the shop where the finished and dried molds have been set preparatory to getting them ready to cast, and we find them lowering the finished and dried core into the mold, where it is centered with the mold, largely by means of an extra core, which in the case of pipe cast bells down forms part of the bead, and for pipe cast bells up forms the inner part of the bell, and in both cases acts as what is known as a "cover plate" for pouring the iron on in casting. After the cores are centered and wedged in position, a pouring box or dam of sand is built up on top of the cover plate, and everything is ready for the pipe to be cast. We now step out in the iron yard for a moment and there find workmen preparing the mix of different grades of iron and the coke, and limestone flux for putting in the cupola or remelting furnace. We follow these materials to the cupola house, and find still other workmen placing these various materials in their proper proportions in the cupolas themselves. From the cupola house we return to the foundry floor, where we find that they have tapped out of the bottom of the cupola a ladle of iron, and are ready to pour or cast the iron in the molds which we saw them getting ready a few moments ago. Do not stand too close, for, if the molten iron spills at any time during the pour, some of it may splash and at least burn some holes in your clothes. Well, that ladle of iron has all been cast into pipe, and the empty ladle is taken back to the cupola spout to be filled again for pouring another batch of molds which the workmen are busily preparing. While the iron is setting and cooling, we will watch them pulling the core bars from the batch of pipe poured previous to the ones we looked at. Here we see the necessity for some means of loosening the bar and why in making the core there is placed first a layer of some inflammable substance, for we notice considerable smoke coming up through the hollow bar, and as the crane is hooked on the bar and it is pulled out, this inflammable material, having charred and partially burned at least, enables the core bar to be pulled, and we see a column of flame follow the bar out as it is raised, which is the final combustion of the separating material. We go still further along the floor to where there is a batch of pipe from which the core bars were pulled some time ago and which have now cooled sufficiently

for them to turn out on the skids. Usually the flasks are hinged on one side and clamped on the other; they are picked up by the crane, taken to the point of turn-out, the clamps knocked off, and the pipe shaken out and rolled out on the skids for cleaning, where we now follow it, and find



Section View Completed Pipe Mold, Core, etc., ready for Casting, together with Operations for Pipe from Mold to Finished Product.

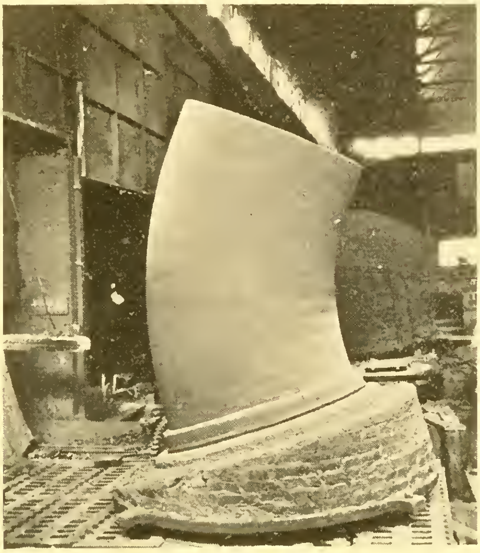
there workmen who are engaged with various tools in cutting out the core sand, knocking any loose sand adhering to the outside off, and then scraping and brushing the dust still clinging to the inner and outer surfaces off and out, chipping off the gates and risers, fins, and lumps, if any. After being cleaned and chipped, they are again placed in ovens and brought up to a temperature nearly as high as the coating material in which they are to

be dipped. After remaining in the reheating oven until hot enough, they are then brought out and lowered or dipped in the hot coating material, drained of surplus coating, and are then ready to be cooled until the coating is hard, when they are ready to be weighed and tested by hydraulic pressure. Each pipe is weighed individually, and the weight recorded on daily reports, and marked in the pipe, and also individually tested. This test is accomplished by placing the pipe in a hydraulic press, which closes on the ends of the pipe against gaskets; the water is then introduced in the pipe and the air exhausted; after the air is all out the air valve is closed and hydraulic pressure to whatever amount is specified is turned on, the pipe examined for leaks or defects, and if all is O.K., the pressure turned off, the pipe released, and it goes on down the skids for disposition either in the stock-yard or on board cars or vessel for shipment.

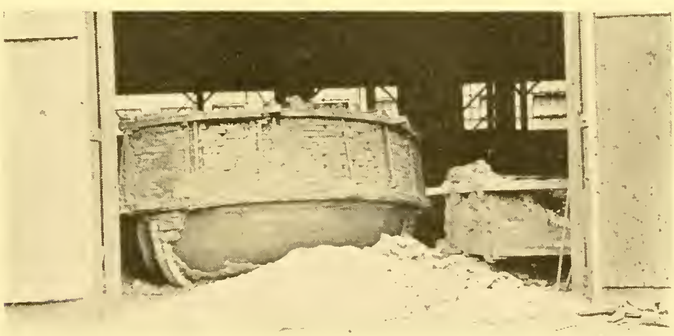
Perhaps you have realized, during this description, the multiplicity of operations that go into the making of a pipe, and yet there are a number of minor detail operations that I have not attempted to describe, for the reason that, though very essential to the production of pipe, the description would occupy more space than their importance in a general description such as this warrants.

We will now go to the shop and look over the way the special shapes known as special castings or fittings are made. Here, while the components for making are termed the same,— pattern, flasks, molds, cores, etc.,— things are carried along differently. For example, generally speaking, castings up to 12 in. or 14 in. are made by what is known as the " green sand " method, while castings larger than 12 in. or 14 in. are made usually by what is known as the " dry sand " method, and for some of the larger castings and of specials where the number of pieces to be made of a given shape is limited and the making of patterns for molding by the ordinary " dry sand " method would be expensive, they are often made up by means of skeleton patterns, or by means of sweeps, and a heavy brick casing built up instead of a flask, and this is known as the " loam " method. The modern shop of to-day uses largely metal patterns, flasks, and core boxes, which means that they can be used repeatedly and indefinitely, with all remaining in good condition; this applies to both types green or dry sand, and in part to loam work. Generally speaking, green-sand castings are made up and cast in a horizontal position, and the term " green sand " means that usually both the mold and the core are made up of a sandy loam with enough moisture to have it compact readily and maintain the shape in which it is formed even when the molten metal is cast. On the other hand, dry-sand molds are made of sand of about the same consistency as straight pipe, and both the mold and the core or cores are dried or have the moisture eliminated. Loam castings as mentioned earlier are those made with sweeps or skeleton patterns, brick casings, and the materials forming the mold and cores are heavy, wet loam made to conform to the form desired, and then baked or dried the same as " dry sand."

You have now had in a general way the methods pursued in producing and finishing pipe and fittings, and perhaps you should have some of the major details more carefully described, for example:



48-inch One-eighth Bend Core Loam, with Mold in Background.



54-inch Quarter Bend in Loam, with Drag removed after Casting.

The iron, including analysis and tests.
The mold. (Body, bell, bead.)
The core.
The cleaning.
The inspection.
The coating.
The testing.

Practically each of these is a story of itself, and susceptible of interpretations widely divergent when viewed from the producing and consum-

ing angles, so that what is now said must be understood to be observations and not expressions of opinion, and reference to previously published articles is not particularly mentioned, though read and found of very considerable help, and confirming things known or observed.

The Iron.

This is a subject of itself, and might well make up a complete paper for a meeting at which there would be no other papers, and yet not be completely told. Before the day of the foundry chemist, mixing of iron for cast-iron pipe was largely a matter of guesswork, and appearance of the color and texture of the metal in the casting usually was judged by breaking off a gate after it had become cold.

The iron used to come to the foundry graded by the furnace producing, whose chemist gave the approximate components. The foundry management in turn figured that so much weight of each of the different makes and grades of pig, together with the scrap composed of fins, gates, and broken-up pipe from previous casts, should go to make the day's melt for the pipe to be poured, the size and weight of the pipe governing the proportions of the various irons. Nowadays, each manufacturer or foundry has its chemist, who analyzes the iron on hand, both pig and scrap, and orders the day's mix by weight, the same as before, but more carefully calculated, and with a more direct knowledge of how the chemical components of the day's cast will line up, for the foundry chemist not only analyzes the raw material but the finished product as well. Scrap in these later days does not mean just the fins, gates, and broken-up pipe, but is a very indefinite term, as the scrap dealer to-day gathers in anything from old stove castings, agricultural machinery, sash weights, etc., up to the very finest grade of worn-out machinery, and unless the pipe manufacturer keeps a very careful check analysis on the scrap he uses, there is likely to be a wide range of components in even a day's cast; and again the blast furnace makes to-day a wider range of grades, and careful check must be kept on the pig in order to keep the iron within reasonable limits.

For pipe from our eastern and northern foundries, cast iron which shows —

Total carbon around	3.5	per cent.
Combined carbon around	0.5	per cent.
Silicon around	1.75	per cent.
Manganese around	.40	per cent.
Phosphorus not over	0.9	per cent.
Sulphur not over	0.1	per cent.

is considered a "fair" pipe iron.

For pipe from our southern foundries the above components will vary somewhat as to their silicon, manganese, phosphorus, and sulphur, and will be considered as making good pipe.

The size and thickness of the castings also go to control the components that can be used, also to some extent, whether in the case of straight pipe they are cast bells down or bells up.

In the matter of physical qualities the transverse test bar has apparently come to be looked upon as the most reliable index of the suitability of the iron. The stresses exerted on pipe for water-works purposes, aside from the backfill and internal stress of the metal itself, appear to demand that the iron not only possess a fairly high degree of strength, but that it be flexible or resilient in order to retain its form without rupture due to variations in pressures and, to an extent, changes of temperature, when in service. Iron that will withstand a load of 2 000 lb. and at this load show a bend or deflection of 0.30 in., the bar measuring 2 in. x 1 in. x 26 in. and being placed and load applied with the 2-in. way horizontal and at the center, the supports for this beam being 24 in. apart, is considered a fair pipe iron. If the test piece is able to withstand a load greater than 2 000 lb., the increase in bend or deflection should be at a rate of 0.02 in. for every 100 lb. of increased load, variations from this indicating, where less, that the iron has a tendency to brittleness, or where greater, that the iron tends to a softer and more open grain. To be sure, a greater variation than .02 in. per 100 lb. of load is more permissible than a less, for, as stated before, flexibility or resiliency are desirable for pipe irons.

These transverse tests of the iron are not absolutely conclusive tests of the iron in the actual casting, and it must be understood are simply an index. Iron when melted and poured into castings becomes a decidedly complex substance, and the only way to arrive at anywhere near a conclusion of the physical properties of individual castings would be to obtain a test piece from every pipe, which would be impractical.

The Mold.

The term "mold" is used to designate the outer form of the pipe or special casting. This is obtained by the use of patterns made up of metal or wood that have been made to the form and of the dimensions desired. In some cases of loam work the forms are obtained by skeleton patterns and the form worked out by hand from the skeleton, or else by placing an outline of the shape desired on a pivot or pole and sweeping up the form desired by rotating the outline around its center pivot or pole.

In the making of molds there are quite a variety of methods employed, from the strictly hand method to various mechanical devices, all designed to obtain about the same result. The strictly hand method means the placing of all of the materials that go to make the mold by hand or manual labor, and naturally they are the slower methods, and while good do not always entail the best results. Of the mechanical methods for straight pipe, there are four that stand out most prominently, and I will only men-

tion them by name, as to describe in detail would take too long; they are the "pull or draw" pattern method; the "rotating and drawing" pattern method; the "mechanical tamping" method; and the "jar rammer" method. For the special castings there is practically but one type of strictly mechanical molding, and that is by "jar ramming," though there are methods which are a combination of hand and machine molding, where the molding sand is placed by hand methods, and the withdrawing of the pattern is done mechanically.

The Core.

The term core is used generally to designate that part of the form for making cast-iron shapes which forms the interior of the casting, and for pipe and special castings gives shape to the barrel, sockets, and — in the case of branches — the arm, and on spigot pieces and, in some cases, flanges, the bead of the spigot and one of the flanges is formed with a core. Cores for straight pipe are made up on an arbor or bar of the dimensions necessary, and for the sockets and beads and flanges in metal forms machine finished to shape and dimensions, and for some shapes of special castings the same methods are pursued, while in others, boxes, sometimes metal and sometimes wood, are machined or cut to the desired form and dimensions; and in the case of loam castings the cores are ofttimes swept up with an outline of the shape desired, revolving from a center pivot or pole.

The Drying.

In the case of dry-sand or loam castings, and with cores made up of wet material, it is necessary to eliminate this moisture before pouring the iron, in order to obtain a sound casting and one true to form, for the reasons that moisture and melted iron are violently opposed to one another; the molten iron coming in contact with water forms strong gases and also chills or sets the iron too rapidly, preventing its becoming a homogeneous mass when cooling or cold.

The customary method of drying is to place the mold or core where there is high atmospheric temperatures, usually an oven where the heat vaporizes the moisture and it is carried off by means of draught chimneys or by mechanically induced or forced draught.

The Pouring.

The work of casting molten iron into prepared forms requires considerable skill, and should only be done by those who have had experience and whose knowledge of the forms as prepared satisfies them that they are in proper condition for pouring, for even with this knowledge accidents occur, either a running out of the metal from the confines of the form it is going into or from a wet mold or core, causing the generation of gases and a type of explosion. In the absence of the use of pyrometers (which are

seldom used), the color and fluid condition of the metal in the ladle after it is run from the cupola tell the man of experience when the iron is right for pouring, and he acts accordingly.

It is extremely difficult to fully describe the technique of pouring iron, and I will not attempt it.

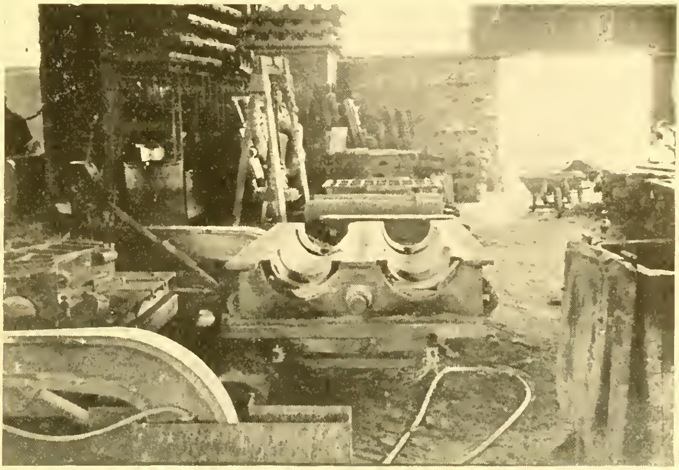


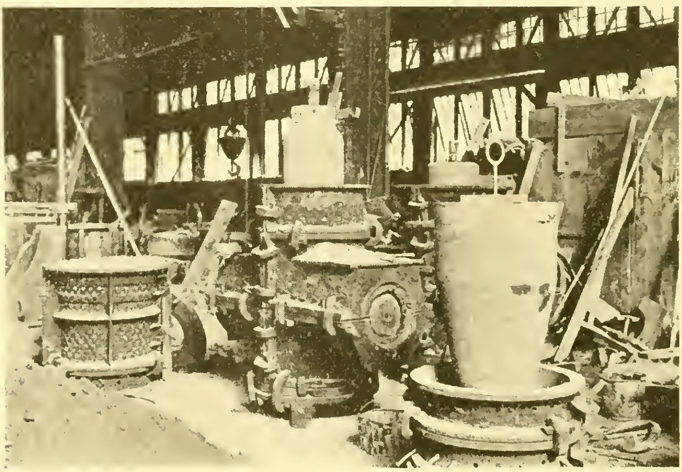
Fig. 2. Reducers in Flask. Green Sand made on Jar Rammer.

Reducer. Dry Sand.

The Cleaning.

It is hard to get — and it would also be very expensive to use in the molds and on the cores of pipe and many fittings — a substance that would work more efficiently than the present-day blacking, which, as

explained, is a made-up mixture of fine-ground coal dust or carbon, molasses, and water. Yet the blacking as used, while it usually prevents the melted iron as poured fusing with the material of the mold and core, there are times when the iron burns through the coat of blacking, causing the sand to stick and entailing much labor and time to clean it off or out of the pipe or casting. Then again because the molds and cores at joints are not an absolute fit there are bound to be fins, and there are always the gates, and risers or projections of iron left on a casting where an opening has been left to allow the escape of gases and for small particles to float out; and all of these, with any sand sticking on, must be cleaned from the casting, so that when this is done the result is practically a finished product. There are various tools used for the cleaning and chipping, such as core-cutting tools, scraping irons, wire brushes, hammers, chisels, dog chisels, picks, etc. Each of these serves its purpose, and with the proper tools a great many pipe and castings can be cared for in a day.



16-INCH BRANCH AND REDUCER IN FOREGROUND. DRY SAND.

THE COATING.

Here is another phase of pipe production, which is as worrisome as "the iron," and at times more so, inasmuch as there does not seem to be a great deal of exact scientific knowledge concerning protective coatings for cast iron. The present specifications for coating are very largely patterned after the Dr. Angus Smith process, which was for a coal tar thinned with linseed oil and the pipe and coating heated to a given temperature, and the pipe dipped at that temperature; present specifications have substituted what is commercially known as "dead oil" for the linseed oil. This is a thin solvent oil of naphtha, and apparently its function is to dissolve the solids in the tar and act as a carrier for helping the tar to soak in the pores of the iron in coating.

When the Smith process was devised, coal tar was coal tar, with many of the natural mineral oils remaining, whereas the tar of to-day may be coal tar or coal and water gas tar mixed, and in a few instances wholly water gas tar, and while to the eye it may all appear very similar, it is none of it like the tar as Smith knew it, for most of the mineral oils have been taken out as by-products. The mineral oils in the old tars materially aided in preserving the coating and the pipe, whereas to-day the tars the foundries are able to get are not much more than a temporary preservative. The older tar, containing as it did the mineral oils, the volume of iron in the pipe heated to a certain temperature and therefore having a certain number of heat units to throw off before the coat set, did not make so much difference, whereas to-day the smaller and lighter classes of pipe, having less heat units to throw off than the heavier classes, the coating keeps better, and the heavier pipe, if heated to as high a temperature as the lighter ones, take so much longer in cooling, that they appear to burn the life out of the tar, which looks good for awhile and then seems to disintegrate.

For all-around purposes there doesn't seem to be anything better for coating cast-iron pipe than tar, yet it would appear that it is going to be necessary to find some alloy to mix with the tar that will put in some of the body and preserving qualities that the old-fashioned tars had.

As an observation it would appear that it might be money well expended to make a fairly extended research to determine the effects on the metal and to some extent the water that the various elements of tar produces, and to have the foundries try analyzing every batch of tar used, and discarding that which has elements that are injurious in sufficient amount to make them harmful, and to try and find some thing or things that will give body and stability to the coating and to prevent the forming of tubercles on the interior of the pipe. In other words, if a coating can be found which while remaining more or less plastic and having sufficient body to make a wearing surface and yet which has no minute air pores reaching through from the metal to the outer surface of the coating,— so minute that they are not discernible, yet they are there,— then there will no tubercles form, for they will not form on the good coating, but hunt for the porous place and enter and fasten on the metal and then start to grow.

The Testing.

Testing the pipe at the foundry is intended to prove three things:

First. That it is within the calculated factor of safety.

Second. That internal stresses in the iron have not been set up in such a way that the hydraulic pressure on the line in service will cause failure.

Third. That there are no gas, dirt, or shrinkage holes; that the pipe is not cracked, and that it is not porous.

As previously stated, the method of testing pipe is to clamp it in a press, fill it with water, at the same time exhausting the air, and then to turn on a higher pressure for actually proving. Foundries can cast and turn out in a day from 400 to 1 000 pipe, the day varying from eight to ten hours.

The plant turning out 400 pipe having possibly 2 proving presses and the plant turning out 1 000 probably 4 presses, the pipe will vary from 4 in. to as large as 60 in. To fill and get the test pressure on a 4-in. pipe takes perhaps half a minute, while to fill and get the test pressure on a 60-in. pipe takes about seven minutes. In testing, the plant that makes 400 pipe will have to prove at the rate of 50 pipe an hour for eight hours, or 40 pipe per hour for ten hours, to get a complete day's work through the test, or 25 and 20 using 2 presses, while the foundry making 1 000 pipe has to prove at the rate of 125 pipe per hour for eight hours, or 100 per hour for ten hours, or 32 and 25 pipe for 4 presses. Except for the larger sizes, say 36 in. and up, the rate of output of pipe is such that it is impossible to allow very much time per pipe for testing, there not being much more than time to fill, exhaust the air, turn on the pressure, and after a very hasty examination pass the pipe down.

Pipe specifications require that the pipe be subjected to a hydrostatic test pressure. If my understanding of the term *hydrostatic test is correct, it means* "*hydraulic pressure held stationary*" sufficiently long to test the object being subjected to pressure, which in the present case is pipe. Now, the foundries do not object to the pressure being held on their pipe, but they have so many pipe to put through (and unfortunately in some of the foundries the facilities for testing have not kept pace with the facilities for manufacturing pipe), with the result that while all the pipe are subjected to test, the period of static pressure is so short that it is a question whether some of the purposes for which the pipe is tested are attained.

THE INSPECTION.

The inspection of cast-iron pipe and fittings, I believe, requires knowledge of a more general character than almost any other material, for it involves knowledge of molding, pattern making, machine-shop practice, chemistry, the cause and effect of the things that happen in the manufacture, and the engineering viewpoint of the materials when put to use, and in addition to all, the inspector should be a man who can and will exercise good sense and sound judgment. Many of the men who take up the work of inspectors are recruited from among the more intelligent of those who have been connected with foundries in the production end, and have acquired thereby knowledge of several of the elements mentioned earlier of molding, pattern making, etc. Some of them go into inspection from the engineering side, acquiring their knowledge of the other matters necessary through study and observation. The actual work of inspection

as generally carried out consists in taking the pipe after being cast and turned out on the skids and following it through the process of cleaning, coating, weighing, and hydrostatic test, to the store yard for shipment. After they are cleaned and before they are coated, each pipe is looked over carefully for defects visible to the eye; they are measured, and gaged for thickness, concentricity, internal, and external diameters at each end, and in the case of fittings or special castings the dimensions of lengths, angles, etc., should be checked over. If they come within the specified limits they are then passed on to the coating and weighing process, and, in the case of straight pipe, to the hydrostatic test; it is not customary unless specifically stated in the contract to subject fittings and specials to hydraulic test, though it would appear that, generally speaking, special shapes due to their shape are not as strong as straight pipe, and, in order to demonstrate that they are within the safety factor, should be tested.

The inspector during the examination determines also whether the iron appears to be approximately as specified, and also witnesses the physical tests of the iron not only at the press but also the breaking of the test bars. He also keeps a record or field book in which notes are made of pipes which in his judgment are unsuitable for the purchaser for whom he is inspecting, and these notes together with the accepted pipes are transmitted in a report to the purchaser. The keeping of these records and reporting them correctly are an important part of his duties.

Of the pipe which are accepted usually the number and the weight is the only notation, and no comment is made, but of those considered unsuitable the cause of rejection is stated. There are numerous conditions which are considered as rendering a pipe and casting unsuitable, some of them of the iron, some of the exterior, some of the interior, and in the case of so-called "uneven," "eccentric," or "lopsided" pipe or casting, of both. All told, the causes for which pipe have been discarded would run as high as seventy-odd, though defects that render pipe or castings actually dangerous are considerably less. Each day we see recorded in the papers accidents of one kind or another, though very seldom is anything said of the vast majority of those who move in safety from point to point or go about their day-to-day lives with nothing particular happening; so it is with pipe and castings, it is the defects that are mentioned, it being found unnecessary to say anything about those which are turned out to take their place and perform their appointed task. So with the inspector,— the pipe he accepts are taken as a matter of course without comment, but the casting which in his judgment is unsuitable is a subject for some comment on both sides, producer and consumer. The broad-minded inspector would rather accept every casting submitted for his examination, and the broad-minded producer doesn't wish him to accept that which his judgment bids him not to; and the purchaser employs him because he wants a first-class article, and has confidence in his integrity to see that he gets it.

For the illustrations which you have seen on the screen, and most, if not all, of those which will appear with the article when printed, the Association and the author are indebted to the United States Cast-Iron Pipe and Foundry Company.

Discussion.

Mr. Henry A. Symonds.* Mr. President, I should like to inquire if Mr. Conard can give us any information on the centrifugal method of manufacturing pipe; if that has at the present time any standing, and if there are any prospects of realizing some of the good things which have been claimed for it.

Mr. Conard. The centrifugal method, as I understand it, was started quite a number of years ago,— I think in England,— and was not successful. Afterwards, I understand, a Brazilian tried out the method and had more or less success, and after trying it out in his own country has applied for and obtained patents in some of the other countries, and it has been tried out to some extent, I believe, in the United States; but the places that tried it have discontinued it, as they apparently have not worked it out to a successful issue. I believe that they are giving it a trial in Canada. Just how much success they are having with it I am unable to say, but they seem to keep on trying. If they could get it to the point of actual practicability it would produce pipe of uniform thickness and very close texture. Some of the pieces that I have seen of pipe produced in that way indicate a very strong, very close-grained iron, and if they could produce them successfully they would be able to produce pipe of equal strength with those made under present methods of much thinner walls.

Mr. Frank A. Barbour. Mr. President, we have here with us this afternoon Mr. Walter Wood, and I always believe in giving the producer a chance to answer any of these critics in manufacturing processes. I would suggest that you give Mr. Wood a chance to say a word.

The President. I thought it was understood, Mr. Barbour, that the floor was open to any one present. It certainly is. We should be very glad to hear from Mr. Wood, or any other of the manufacturers.

Mr. Walter Wood.† Gentlemen, there are only, I believe, eight different parties manufacturing cast-iron pipe in the United States, from the Pacific to the Atlantic, and Mr. Conard has so kindly instructed the 150 people who are here that we will probably have that number very much increased. To that extent I hope his paper will bear fruit, so that the country will be dotted all over with cast-iron pipe manufacturers.

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* Consulting Engineer, Boston, Mass.

† Of R. D. Wood & Co., Philadelphia, Pa.

Mr. Conard has given a very interesting and a very correct description of the manufacture. There is one point that I would have been glad if he had mentioned, and that is in regard to the bar which is used in the breaking. The dimensions that are taken for that bar are chosen because there is a regular coefficient between the breaking of that bar and the tensile strength. A bar that is broken between 24-in. centers, 2 by 1, broken on a flat, is 10 per cent. of the tensile strain of the iron. It is the easiest, quickest, and — unless you go to the elaborate preparation of the direct pulling — the most convenient way of reaching the tensile strength of the iron. As regards centrifugal pipe, Mr. Conard gave you as full an explanation of its status as any one can at the present moment. The first centrifugal pipe made I saw between thirty-five and forty years ago. My impression of the results of centrifugal casting of the pipe is that the requirements for thickness and weight, according to the present specifications, are so narrow that it would be very difficult to make a pipe that would come within those variations. To that extent the centrifugal molding, even if the cost was not considered, would be very difficult to secure. As regards its cost, the expense of molding by sand,— without having any cost figures except those of the present mode of casting, I should think it would be markedly less than the centrifugal method. The upkeep of the machinery and other details of manufacture, I take it, would make it impossible to compete by the centrifugal method with the plain, old-fashioned sand method which, after all, is very simple. The sand method has its troubles, but I think the centrifugally-cast pipe will be much more liable to defects and need Mr. Conard's careful inspection before it is sent out to the users.

My experience with cast-iron pipe commenced sixty-seven years ago, and I think I can handle most questions relating to it.

Mr. Barbour. I should like to ask one question of Mr. Wood: Why is it that present rejections run so high in some of the foundries as compared with others? Is it in the iron, the quality of the iron used, or the methods of manufacture?

Mr. Wood. That results from a number of causes. The percentage of rejections in the past six or eight years has been abnormally high. The old set of men have been drawn away from their work, and getting in all new men has been a very, very great labor. I think the trouble has been due to the crude and unskillful workmen that have been forced upon the manufacturers.

The percentages of rejections also are very largely of two kinds,— one which makes the casting unfit for the use for which it is intended; the other is from the technical requirements of the specifications, which interfere with the choice of the castings for practical purposes. The requirements of the specifications are so narrow that pipe which will answer for use in one place will cause rejection in another. And the difficulty of getting good workmen and good metal, and, above all, getting good coke,

has thrown a very great burden upon the manufacturers, the last six or eight years.

Mr. Conard. Speaking of the rejections; as Mr. Wood says, they are from two causes,— the putting together of the materials that go to make up the mold and the core,— which is the labor end,— and the iron. Of course the iron is a matter of controlling the material which you are putting into the mold. On the labor, as I view it, the defects of human nature, the defects of workmanship, are the lack of skill on the part of the workmen, and the difficulties of controlling the human factor, which, as Mr. Wood says, are at the present time very great, and will have to be, in my judgment, to a greater extent than up to the present, offset by the creation of mechanical devices which will perform many of the operations of making pipe which are now performed by hand.

Mr. Frank A. McInnis. I had hoped that with this stage set as it is to-day, with Mr. Conard here as an inspector, and Mr. Wood with his sixty-seven years of experience,— which is enough for us,— that all of our members might take advantage of the occasion, and not accuse, as I have often heard, that the talking was all done by two or three people. Now, here is surely a chance, if there ever was. All of these men here use pipe. Let them tell what their troubles are, ask what they want to know. There never was a better chance.

Mr. Percy R. Sanders. One pipe manufacturer told me the reason that he had put a little higher price on his pipe than some of the others was because they cast their pipe spigot up and then put it in a lathe and cut off every length. I should like to know if that is a custom that is going to come into practice, and if it is a good custom.

Mr. Wood. The question of cutting off the end of the pipe is largely a question of the character of metal that is used, the method of manufacture, handling and cost. The English practice is to cut practically every pipe. The European practice is not to cut pipe. The American practice has been, up to date, not to cut their pipe, but there is a tendency now to do so, as it has been rather forced by the character of the workmen that we have had to deal with in the past five years. Cutting the pipe adds about 3 per cent. to the cost, because if you take off from 144 in., 4 in., you can readily calculate the amount of loss that is occasioned. But every pipe which has a bad bead, which is the place where the defects occur, should be cut.

Mr. Samuel E. Killam. Mr. Wood probably realizes as much as the rest of us, especially those who deal in the larger pipe, that the quality of the coating that we have received in the last few years has gradually deteriorated. From his sixty-seven years of experience, does he think that it is going to continue this way, or may we expect something better in the next few years than we are now getting in coating? Have we got to suffer on account of the by-products in the tar?

Mr. Wood. The coating question is an exceedingly interesting one. The expense of the coating as now applied is almost infinitesimal. The cost of the coating per ton of pipe runs into but a few cents. The character of the coating in the past probably was a little better than it has been in the last few years, because of the character of the tar that we have been getting. I think when the tar that we are now using is bettered by more oil in the coating, it will probably overcome very much the difficulties which we have all more or less appreciated.

I should like to have Mr. Conard express his thought upon that question.

Mr. Conard. *Mr. President and Mr. Wood,*— Of course what I said in the paper was simply an observation, but it really expresses my thought in the matter, in that I believe it would be money well expended, both by the consumer and the producer of pipe, if some more careful research work were done on the question of coatings than anybody has attempted in the, at least, recent past. The older tars, as they were used, retained and held the mineral oils. The preservative oils were not distilled out in the old days as they are at the present time, and it means putting back into the present-day tar, if we are to continue to use that,— and there does not appear to be anything better at the present time,— something that will restore to that tar its lasting quality and yet not be so heavy or thicken up the coating to such an extent that it acts just the reverse of what we desire. Just what those oils should be, just what that mixture should be that we should put back into the tar, is the crux of the situation. There has been no research work gone through with to tell us what should be put back there, what the oil or oils should be that should go back in the tar to restore it to the condition to make it as good a coating as it one day was.

And then the question of temperature should be gone into. The temperature should, in my judgment, be varied for varying sizes and thicknesses of pipe, because the number of heat units that are thrown off before the pipe becomes cold, or cools, and the coating becomes hard, has much to do with it. If the body of the pipe is so heavy, and the heat units are so many that it drives the life out of the coating, you might almost as well not have any coating at all.

Mr. Mosteller.* We believe in and do cast all pipe bell end down with a riser above the spigot end at all of our foundries except our Scottdale plant, and cut off the riser from above the 12-in. length of pipe. I am told by our production men that since this practice has come into general use, losses have been very much reduced; in fact, on large pipe that there is practically no loss.

The practice of casting pipe with the riser varying in height and thickness with the thickness and diameter of the pipe, such riser afterwards being cut off in a lathe, insures absolutely sound metal in the bead of the pipe, and it is almost axiomatic that if you have good sound metal in the

* Of U. S. Cast-Iron Pipe and Foundry Co.

bead of a vertically cast pipe it means sound metal throughout the casting, in that the iron in setting draws down from the bead, and with a riser which is considerably thicker than the wall of the pipe and with a considerable height to it, the action is like that of pouring lead, for as the iron in the body of the pipe sets, there is constantly a head of fluid metal above to fill up any slight draws or voids which might be formed.

Another very important feature is the fact that it does away with any spongy beads in themselves. In the old manner of casting, the bead (except for the few points at which it was gated) came up against a cake which chilled the iron. This frequently held in the spigot gases which formed blowholes and gave a spongy spigot, although the casting skin over the end of the spigot would not show this. The result was the spigot end was always given very careful scrutiny and was severely attacked by hammers to see if any of these voids existed. Naturally this excessive picking was not a good thing for the appearance of the pipe, nor did it increase its usefulness, and frequently did not go deep enough to discover the defect searched for. In casting pipe with a riser, we accomplish also the purpose of bringing up any dirt or sand which may be loosened in the mold in the pouring of the iron. This naturally floats to the surface and comes up as the pipe is poured and is carried off in the riser. Another thing that we get away from is the breaking off of the runner gates. Frequently in knocking off the gates the spigot end would be broken into slightly, sometimes so greatly as to cause the loss of the pipe. The lathes used in doing this work are specially constructed. The cutting off of the riser is a slow process. The handling of the pipe in addition to the cutting adds expense to the cost of making every piece of pipe. This manner of casting entails considerable expense, which we have assumed, believing that it is a large step forward, insuring the purchaser absolutely sound material. We hope by making pipe in this manner to have it come into vogue and that purchasers will demand pipe made as we cast ours. This will insure a cylindrical pipe of homogeneous metal, clean and free from dirt and dross.

This little piece of iron which I have here is a section cut from the riser of an 8-in. pipe. I had this cut in the machine shop, to see the contents of the iron and dirt which had risen into the riser, partly from curiosity. I found from this piece and other risers cut up that it was very spongy and full of holes, — "buggy," as the foundrymen call it. This shows clearly that there is dirt and dross in all iron which has been forced to the top and out of the pipe. I believe that the piece of pipe from which this riser came was theoretically and practically a clean pipe. This operation increases our cost on each pipe, and, as Mr. Conard has pointed out, there are 31 major operations in making a piece of pipe. There are many other minor details in manufacture. All of this goes to show that there is a great deal of hand labor in making pipe. Very few men, outside of the ones who have gone into modern foundries, realize that pipe requires so much care and so much labor.

The United States Cast-Iron Pipe and Foundry Company is not trying to increase the cost of pipe, but these additional operations, to the ones Mr. Conard mentioned, will show you why our cost per ton has been increased. We do not attempt to get this additional cost of, say, $1.75 to $2.25 per ton, or whatever it may cost us to make pipe over the old method, for you know that in general competition we cannot get an additional price, nor do we try to get it. I have had buyers say to me recently, and I believe it is true, for they have been practical men and mechanical engineers, that if they could get pipe made as we make it, showing a clean barrel and a perfect spigot, they would be willing to pay a dollar per ton extra. We are not talking for higher prices, and this explanation is made in answer to Mr. Sanders's question.

(*To Mr. Sanders.*) The statement you referred to was evidently made by the speaker, and if you will recall he said that the cost was there, but we do not attempt to get it, and that we are not trying to advance the selling price of pipe.

Mr. McInnis. How far is the cost offset by fewer rejections, a lesser percentage of rejections?

Mr. Mosteller. My understanding in answer to Mr. McInnis's question is that our losses have been reduced to such an extent that in normal times, when there is large tonnage in the shops, we can practically write off that expense. In other words, where we use to lose a certain percentage of pipe on account of bad, rough spigot ends, we now save these pipe by the methods of manufacture given above. The old theory was, that bad spigots made no difference because they went into the bell and were calked with lead. Practical pipe-layers and engineers who are studying all improvements in pipe-making say that they now feel safe when using pipe made by this method.

A prominent gas engineer told me, some time ago, that these clean spigots had reduced their leakage to almost nothing. With a normal tonnage in the foundry I would say that we could almost write off the expense of casting pipe with the riser and cutting it off in the foundry, for the reason that we gain many pipe which we formerly lost, which reduces our costs and our customers' inspection charges.

Mr. Leonard Metcalf. It has occurred to me that it might well be possible for our cast-iron pipe committee to interest the National Research Council on this question of the coating of the pipe, and to get it to undertake a series of tests along the line suggested by Mr. Conard.

Mr. Henry V. Macksey. Mr. President, it seems to me on that line that Mr. Conard is passing the buck very easily. He said the producers and the consumers should take this matter up. But to-day we have testing laboratories and big engineering outfits to study and advise, not only that the work is carried out according to specifications but to advise as to the specifications. I believe this investigation belongs to them, and that is what they are paid for.

Mr. Edward D. Eldredge. This subject of coating is certainly a very important one. It would seem that under the present conditions the benefits are only of a temporary nature as far as the interior is concerned. It would be interesting to know if any experiments have been made, successfully, in lining cast-iron pipe with cement. The reduction in area would not be nearly as serious an item as the reduction which now occurs through tuberculation.

Mr. Conard. I do not think there has been very much done, if anything, on that, in the way of experiment. That might be something for either the Pipe Specifications Committee, or our friends the manufacturers, or our testing laboratories to go into.

Mr. Macksey says I "passed the buck." I do not think I did. Who is going to pay the bill? It is admitted that the research work ought to be done, but who is going to pay the bill for it? My belief is it ought to be a combination. The manufacturer is in the business of producing cast-iron pipe, and he is in the business of producing cast-iron pipe in accordance with the specifications provided by the consumer, and those specifications in part say as to what the coating shall be and how it shall be applied, etc. So far as the manufacturers are able to get the materials they comply with those specifications, and they put a coating on that is to all intents and purposes in accord with those specifications. And yet I think that the manufacturers will admit that they are not altogether satisfied with the result, and most assuredly the consumer is not satisfied. Now, should not the producer and the consumer go into a careful and thorough research? And let me tell you, if you are not going to go into it thoroughly and do it as thoroughly as it should be done, there is no use in doing it at all; but if you do go into it as thoroughly as you should, it is going to cost something. And the consumers should be prepared to pay their proportion of the bill, and for the satisfaction that the producers would have in giving the goods to the consumer as a result of some such work, they ought to be willing to pay some portion of the bill also.

Mr. Metcalf. I made the suggestion that I did, Mr. President, for the very reasons stated by these various gentlemen,— because the cost must ultimately be borne by the consumer. It will be burdensome if undertaken by any one consumer; it will be burdensome if undertaken by any one manufacturer. The work cannot be done unless it is done on a large scale, which will cost a lot of money. It takes money to organize and to make the test. We have the organization in the National Research Council. It has done just this sort of thing, I understand, through various agencies, getting collections from those who were interested and who were willing to contribute to an investigation from the results of which everybody would benefit. It was for that reason that I suggested that organization. I feel quite confident that it might be interested.

Mr. Barbour. Mr. President, in connection with the subject of coating, I think we have missed one point, namely, that this is the age of

production. All these foundries want a mass product,— to rush it through. In the old days of Angus Smith the specifications required that the pipe should be put into the vat and left there until it came to the temperature of the dip; that would be too slow for present ideas of output. It is practically impossible to get a non-cut back tar to-day, but, even if it were possible, I question very much if we would get the result that they got in the old days when they took more time.

By excessive temperature of the pipe when dipped we probably volatilize or drive off certain constituents in the coating. I had an experience in that connection. In a 36-in. steel line installed at Akron, Ohio, some years ago, which was lock bar pipe made at Paterson, N. J., we started out to use tar, and we did get non-cut back tar after a great deal of effort. We found that the coating of tar on one side of the pipe would be perfectly satisfactory, and on the other side it would be chippy and brittle. The pipes were heated in horizontal ovens, and to determine whether the question of temperature was not the controlling factor I had about a dozen alloy buttons made,— little pills of varying alloys that would melt at differences of 25 degrees of temperature. We found by putting these alloy buttons on the pipes that, whereas one side of the pipe might be only 300 degrees, on the other side it would be as high as 700 degrees. And we followed that through and found that the high temperature side of the pipe was where the coating was brittle, and the lowest temperature side where the coating was soft.

RAINFALL IN NEW ENGLAND.*

By X. H. Goodnough.†

In a paper on Rainfall in New England, published in the Journal of the Association for September, 1915, the writer presented copies of the rainfall records in New England which were then found available, including observations at stations in adjacent parts of New York and Canada up to the end of the year 1913. In the present paper, in accordance with the desire of the Association to bring up to date the various records of rainfall, stream flow and yields of watersheds as presented in previous papers and reports, the tables of rainfall observations in New England and its immediate neighborhood since 1913 have been collected and are presented herewith up to the end of the year 1920.

The plan followed in the previous paper has been continued in presenting the copies of the rainfall records since 1913, and the records are presented by states in the following order: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut. Observations in adjacent portions of New York and Canada are appended in the order named. The stations are again arranged alphabetically by towns, except in a few cases, where the name of the station is better known in connection with rainfall observations than the municipality in which it is situated, as, for example, Bar Harbor (Maine), Chestnut Hill (Mass.), Lake Cochituate (Mass.), etc.

In printing the names of observers the same plan has been followed as in the previous paper. Observations made by the U. S. Weather Bureau, or reported regularly to that office, are presented without designating the observers. In other cases the name of the public department or corporation, if known, is printed at the head of the table.

The tables have been rechecked, and in some cases it has been possible, since the previous records were published, to compare the published tables with the original records. These comparisons have shown very few errors in the previous tables, no errors of importance being found excepting in the tables of rainfall observations at Monson and Waltham (Water Works), Mass. These tables, upon comparison with original records which have since become available, have been found to contain numerous errors, and are accordingly republished in the present paper and should be substituted for the tables on pages 363 and 382 of the Journal for September, 1915.

* In the preparation of this paper the writer has had the assistance of Mr. George V. White, of the Engineering Division of the Department of Public Health, in the collection of the data and much of the information relating thereto, and clerical assistance from other members of the office force, particularly Miss Penney and Miss Drake.

† Chief Engineer, Mass. Department of Public Health.

Since about the time of the presentation of the previous paper to the society, some 80 new rainfall observation stations have been established within the limits of New England, and a few have been discontinued. Of the new stations, 48 are in Massachusetts, 12 in Vermont, and 5 or 6 in each of the other states, excepting Maine, which, while its area is the largest of all, contains only 2 of the new stations.

It has been possible also to add a few long records of rainfall observations which were overlooked in the publication of the previous paper or with the existence of which the writer was not acquainted. Among these in Massachusetts are a rainfall record of about 20 years at North Billerica; a record covering 25 years at Boylston, near the Wachusett Reservoir; a record from 1878 to 1885 at Fresh Pond, Cambridge; a record at Woods Hole, in Falmouth, from 1873 to 1900, with a gap of 5 years from 1882 to 1886 inclusive; a record at the Marlborough Water Works, from 1900 to 1920 inclusive, and a record at Sharon, from 1903 to 1920 inclusive. In Rhode Island, a record at the Clyde Print Works, at Hope, beginning in 1889, is included; also the U. S. Weather Bureau station at Providence, beginning in 1905. In Hartford, Connecticut, a U. S. Weather Bureau record for 22 years has been added to the tables.

In the course of the studies of rainfall observations it has been practicable to inspect a large number of rain gages in various parts of New England, and also to compare various types of gages placed at the same station. It is not practicable to present an account of these observations within the limits assigned to this paper. It may be said, however, that so far as the writer's investigations have shown, the standard 8-in. rain gage, properly cared for, appears to furnish the most reliable observations of precipitation, under various conditions, of any of the gages in common use. Measuring snowfall upon any prepared area is difficult in any case, and in many storms impracticable, especially in southern and eastern New England, where rain and snow are often mingled in the same storm. This difficulty was pointed out clearly by the Rev. Manasseh Cutler, who kept rainfall observations in Ipswich in 1782, and whose remarks relative to the matter were quoted in the previous paper on this subject.

It is also difficult to measure the snowfall accurately in a rain gage, both on account of the danger that in some exposures some of the snow is likely to be blown out of the gage, while, on the other hand, at times of high wind the precipitated dry snow is often blown into the air, and unless care is taken the reading of the depth of snow collected in the rain gage may be enhanced thereby.

Variations from these causes appear to be less likely to occur with an 8-in. standard gage than with gages of greater diameter in proportion to the depth; but in setting up a gage it is important to select a location where variations are unlikely to be caused by snow being carried either into or out of the gage by the wind. The top of a standard gage, when set up in the stand usually provided for it, is commonly elevated about 3.0 ft.

above the ground, but this elevation is inadequate to prevent the snow from covering the gage in some parts of New England, and, in fact, in most parts in years of very deep snow. The danger from this cause can usually be avoided by raising or lowering the gage from time to time as the variations in the depth of snow make changes necessary.

While the variations between the standard and other gages, so far as observations thus far made have indicated, are usually greatest in winter, considerable variation has sometimes been found in other seasons between the amounts collected by the standard gage and by gages having a larger diameter in proportion to the depth. This variation, while usually small, may nevertheless be large enough to affect materially calculations of the yield of watersheds, and it is most desirable that standard gages be set up for periods of several months alongside of gages of other types in use in order that any differences may be noted and allowance made for them in comparing observations in the same region in gages of different types.

The accuracy of rainfall observations depends, of course, very largely upon the faithfulness of the observer, and a carelessly kept record may be worse than useless because it is misleading. It is desirable, before using a rainfall record upon which dependence must be placed in making important calculations, to note whether it shows any serious or unaccountable differences when compared with other records in the regions, and, if so, to obtain information as to the location of the gage and the probable accuracy with which the observations have been kept.

As in the case of the earlier publication, fragmentary or obviously inaccurate or defective records have been omitted, but discussion or remarks as to the comparative reliability or value of the various records has not been attempted.

The elevations of the stations are given as nearly as possible; a few are unknown.

In a few cases, where the records are incomplete, figures have been interpolated from other records at stations where the conditions appear to be similar. These interpolated figures are printed in heavy type and have been used in making the averages.

MAINE.

RAINFALL AT BAR HARBOR, ME. Elevation, 20 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.00	1.89	4.15	3.15	1.30	**2.79**	2.85	3.49	0.50	**2.30**	3.15	1.95	31.52
1915	**5.90**	3.07	T	**3.50**	**2.60**	**2.58**	**7.30**	**4.27**	**0.91**	2.35	4.22	3.50	40.20
1916	1.89	3.52	4.35	3.85	3.50	4.04	4.32	2.83	3.60	2.58	2.94	4.53	41.95
1917	5.48	3.67	4.96	3.73	4.70	10.29	3.56	7.14	2.50	6.72	2.16	3.11	58.02
1918	4.61	4.35	2.20	4.70	1.14	4.10	2.31	3.53	9.77	6.78	5.10	3.31	51.90
1919	2.54	3.13	6.63	4.94	3.24	1.82	3.61	4.92	6.95	3.85	6.05	3.30	52.98
1920	3.16	6.67	5.23	11.05	2.33	3.13	**2.45**	**2.97**	**5.77**	**1.65**	**4.20**	**4.68**	53.29
Av. 44 yrs.	4.90	4.05	4.96	3.60	3.33	3.30	3.41	3.40	3.70	4.39	4.81	4.44	48.29

RAINFALL AT BRIDGTON, ME. Elevation, 450 feet.
(North Bridgton.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.53	1.47	4.65	5.12	1.52	2.74	2.70	3.70	0.58	1.63	2.99	1.96	31.59
1915	3.41	5.21	0.07	2.74	1.62	1.48	11.03	7.05	1.64	2.15	2.87	4.03	43.30
1916	1.67	4.36	2.51	5.04	6.45	6.95	3.58	7.83	4.84	2.15	4.25	4.50	54.13
1917	3.86	2.47	3.81	3.02	3.75	11.20	4.28	7.48	0.52	4.68	0.99	2.91	48.97
1918	3.55	2.50	1.34	2.37	2.43	5.44	4.55	3.74	8.72	4.11	2.70	3.84	45.29
1919	3.70	1.80	5.12	2.05	5.24	1.61	4.03	2.25	4.52	4.29	5.19	1.49	41.29
1920	1.51	5.38	5.06	7.28	2.51	2.48	3.69	4.99	5.90	1.97	5.01	8.02	53.80
Av. 27 yrs.	3.41	3.52	4.05	3.44	3.56	3.74	4.32	3.76	3.87	3.26	3.46	3.52	43.91

RAINFALL AT CORNISH, ME. Elevation, 778 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.87	1.94	4.95	5.45	1.57	3.81	4.58	5.98	0.84	1.17	3.27	2.54	38.97
1915	4.00	5.54	0.21	3.22	1.08	1.36	10.42	4.94	1.64	3.50	3.81	4.01	43.73
1916	2.09	5.83	4.10	6.23	5.46	7.83	4.53	4.13	3.88	2.62	3.73	4.76	55.19
1917	4.34	2.02	4.26	3.34	3.02	12.26	1.48	7.21	1.18	5.25	1.17	2.75	48.28
1918	2.72	2.89	1.32	2.91	2.47	**4.08**	**3.74**	4.86	9.02	2.83	3.25	4.55	44.64
1919	3.51	1.86	5.29	2.84	5.48	1.70	3.19	2.21	4.28	3.54	6.88	1.89	42.67
1920	2.20	5.63	5.19	7.17	2.99	2.95	4.25	5.83	6.99	1.29	4.88	6.86	56.23
Av. 64 yrs.	3.52	3.66	4.26	3.59	3.59	3.65	4.19	4.36	3.65	4.04	4.15	3.63	46.29

RAINFALL AT EASTPORT, ME. Elevation, 53 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.18	2.26	3.77	3.93	0.80	3.23	1.21	2.54	2.92	2.56	2.78	1.95	32.13
1915	5.80	2.57	0.57	3.58	3.14	3.45	3.75	2.68	1.21	1.86	2.16	3.82	34.59
1916	1.86	2.65	1.64	2.57	1.38	3.79	4.87	1.82	2.41	2.73	2.12	3.98	31.82
1917	3.87	2.79	2.95	3.22	1.62	7.40	1.90	4.44	1.51	4.01	1.72	2.99	38.42
1918	2.88	3.95	2.17	2.10	1.50	3.26	2.98	1.67	4.65	3.33	2.00	2.31	32.80
1919	3.06	1.86	2.67	2.15	3.98	1.25	2.82	2.98	3.85	3.36	4.10	3.02	35.10
1920	2.07	6.40	4.36	4.21	1.26	1.95	1.23	2.10	3.38	2.18	2.52	3.31	34.97
Av. 52 yrs.	3.80	3.32	4.00	2.96	3.34	3.21	3.22	3.16	3.00	3.91	3.65	3.67	41.24

RAINFALL AT EUSTIS, ME.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.43	1.61	4.09	4.00	1.61	2.84	2.53	3.02	2.31	3.34	2.25	1.86	30.89
1915	2.60	2.54	0.11	2.36	1.69	1.66	7.11	3.44	2.43	1.48	1.95	3.91	31.28
1916	1.73	2.85	1.65	2.86	4.75	5.14	3.82	5.58	2.41	1.66	3.42	3.56	39.43
1917	2.21	1.70	2.17	2.16	2.65	8.12	3.15	6.75	2.10	**6.13**	0.97	**3.74**	41.85
1918	1.81	2.18	2.28	1.22	3.65	2.35	3.74	1.95	5.98	6.39	3.16	2.19	36.90
1919	2.23	1.15	3.15	2.77	**4.17**	3.43	2.60	3.33	3.33	4.50	3.57	1.04	35.27
1920	1.59	3.60	2.97	3.08	1.38	4.02	4.40	3.32	4.61	2.43	4.04	5.27	40.71
Av. 7 yrs.	1.94	2.23	2.35	2.64	2.84	3.94	3.91	3.91	3.31	3.70	2.77	3.08	36.62

RAINFALL AT FAIRFIELD, ME. Elevation, 90 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.54	1.85	3.40	4.64	0.73	1.38	0.93	3.36	0.68	1.62	1.58	1.14	22.85
1915	3.26	3.46	0.13	2.41	0.91	0.85	7.78	4.96	1.31	2.50	1.21	2.66	31.44
1916	0.89	1.72	1.48	1.52	2.18	2.93	1.75	4.23	3.35	2.49	**4.64**	**4.37**	31.54
Av. 30 yrs.	2.96	2.68	3.14	2.32	2.78	2.52	3.38	3.24	2.79	2.72	2.70	2.94	34.17

RAINFALL AT FARMINGTON, ME. Elevation, 450 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.18	1.81	5.32	4.90	1.62	2.67	2.68	1.41	1.71	2.28	3.15	2.16	34.89
1915	3.51	4.21	0.13	3.12	2.66	2.47	7.54	3.89	2.02	2.32	3.15	4.08	39.10
1916	1.49	4.21	2.23	4.28	6.79	5.14	3.95	7.50	5.25	2.29	4.18	4.62	51.93
1917	3.89	1.90	4.21	3.19	2.85	10.74	2.55	7.14	1.69	5.86	1.12	3.86	49.00
1918	2.56	2.38	1.91	2.46	3.19	4.98	3.58	2.35	8.98	5.59	4.15	3.56	45.69
1919	2.62	1.51	5.79	2.57	5.77	3.10	2.49	2.57	5.08	4.15	5.43	1.49	42.57
1920	1.54	6.01	3.24	6.57	2.26	2.08	3.34	7.20	6.70	2.51	6.01	8.81	56.27
Av. 30 yrs.	3.37	3.12	4.05	3.17	3.61	3.69	3.60	3.87	3.79	3.36	3.51	3.54	42.68

RAINFALL AT GARDINER, ME. Elevation, 163 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.38	2.55	4.09	5.26	1.93	4.23	2.58	3.77	0.67	1.92	2.10	2.24	33.72
1915	3.83	4.02	0.12	1.89	2.41	2.01	9.17	3.92	1.21	2.95	3.08	3.74	38.35
1916	1.87	3.85	3.25	4.00	4.65	4.45	3.30	3.01	3.14	2.59	3.44	5.71	43.26
1917	4.24	2.57	4.79	3.04	2.22	8.88	2.25	4.80	0.71	5.16	1.33	2.64	42.63
1918	2.06	2.45	1.54	2.55	1.16	4.62	7.06	4.42	7.98	3.99	3.46	4.13	45.42
1919	3.99	1.61	4.90	2.37	3.92	2.07	1.84	1.92	5.06	5.42	4.00	1.85	38.95
1920	1.40	5.62	3.70	7.87	2.07	2.74	5.73	2.40	7.75	2.68	3.37	5.48	50.81
Av. 84 yrs.	3.62	3.47	3.95	3.30	3.60	3.23	3.40	3.49	3.39	4.10	3.95	3.69	43.19

RAINFALL AT GREENVILLE, ME. Elevation, 1 140 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.39	1.92	4.15	4.51	1.70	3.34	2.62	2.90	2.68	3.07	2.10	1.50	33.88
1915	3.03	4.36	0.24	3.49	2.99	2.00	8.98	6.13	3.74	1.83	2.56	4.84	44.19
1916	2.35	3.34	2.35	2.45	4.59	3.99	5.60	2.95	4.23	2.87	4.17	4.87	43.76
1917	3.95	1.90	3.90	3.25	3.22	8.69	6.97	4.98	1.80	6.40	1.26	3.62	49.94
1918	2.49	2.47	2.19	1.66	3.37	3.38	8.25	1.42	6.52	5.38	3.77	3.49	44.39
1919	2.85	2.27	4.03	2.96	4.76	2.25	5.82	3.77	3.71	4.13	3.58	1.81	41.94
1920	2.84	4.52	2.85	5.40	1.33	3.12	1.46	4.61	5.60	3.22	3.75	6.93	48.63
Av. 15 yrs.	2.88	2.92	3.31	3.02	3.45	3.76	5.33	3.93	4.30	3.86	3.23	3.49	43.48

RAINFALL AT HOULTON, ME. Elevation, 362 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.95	0.90	1.20	1.27	1.20	4.05	1.31	1.01	1.35	2.21	1.50	0.80	18.75
1915	2.31	1.14	0.35	1.63	4.19	1.32	4.03	2.17	2.37	1.52	1.46	3.85	26.34
1916	2.15	3.20	0.95	1.35	1.09	2.62	4.32	1.57	1.42	3.16	2.15	4.13	28.11
1917	2.35	1.20	2.17	1.74	1.90	6.91	3.69	4.89	1.97	4.97	0.90	2.80	35.49
1918	2.40	1.75	1.70	1.23	0.39	2.00	2.86	1.51	5.15	4.38	2.05	1.77	27.19
1919	2.00	1.25	2.02	2.75	3.26	1.87	1.57	0.46	4.48	2.05	2.94	1.63	26.28
1920	2.30	3.20	2.18	2.50	**0.96**	0.60	**3.66**	**3.02**	7.96	3.15	2.60	2.16	34.29
Av. 18 yrs.	2.31	2.07	2.24	2.04	1.93	2.53	2.59	2.40	3.08	3.05	1.87	2.15	28.26

RAINFALL AT LEWISTON, ME. Elevation, 185 feet.

(Union Water Power Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.76	1.93	5.04	5.12	2.44	2.92	3.00	4.54	0.53	1.61	2.92	2.50	35.31
1915	4.29	4.78	0.17	3.32	1.81	1.89	9.52	4.25	1.13	2.83	3.55	3.99	41.53
1916	2.18	4.64	2.49	4.76	6.46	4.65	3.35	2.69	2.99	2.47	4.12	4.46	45.26
1917	4.14	2.07	4.44	3.34	2.88	11.16	4.34	4.45	0.62	6.71	1.10	4.21	49.46
1918	3.18	2.44	1.35	2.56	2.55	3.83	6.86	4.95	7.70	3.29	3.86	4.22	46.79
1919	3.59	1.80	4.71	2.38	4.78	0.93	2.85	1.94	4.65	4.34	5.89	1.97	39.83
1920	1.72	7.56	5.80	7.00	2.04	2.19	3.58	2.71	9.27	2.31	4.35	7.54	56.07
Av. 46 yrs.	3.91	3.84	4.41	3.35	3.42	3.51	3.73	3.27	3.59	3.68	3.88	4.04	44.63

RAINFALL AT MADISON, ME. Elevation, 257 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.72	1.32	5.54	6.42	2.41	3.23	2.38	6.76	1.76	3.77	3.53	2.19	42.03
1915	4.21	5.27	0.31	4.78	2.50	2.00	7.98	3.69	2.20	2.46	2.94	3.39	41.73
1916	1.84	3.91	2.05	4.32	6.73	5.14	3.28	6.93	5.12	2.19	5.21	3.63	50.35
1917	3.12	1.51	3.95	3.03	2.69	9.96	2.37	5.46	2.09	5.10	0.28	3.08	42.64
1918	2.65	2.42	1.82	2.81	2.32	3.93	6.19	2.36	7.13	4.50	4.35	4.36	44.84
1919	2.09	1.80	4.56	3.10	4.97	1.82	3.05	2.06	3.47	4.05	3.90	1.38	36.25
1920	1.69	5.62	1.73	4.99	1.80	2.15	3.33	4.40	7.94	1.11	4.46	7.94	47.16
Av. 19 yrs.	3.35	3.05	3.84	3.88	3.72	3.83	4.26	4.44	4.29	3.86	3.31	3.43	45.26

RAINFALL AT MILLINOCKET, ME. Elevation, 386 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.71	1.60	4.43	4.18	1.11	3.56	3.79	3.05	2.06	3.16	2.74	2.40	35.79
1915	3.76	3.48	0.11	4.41	3.50	2.12	5.48	3.51	3.13	2.08	2.85	4.40	38.83
1916	1.57	2.98	1.64	2.39	4.01	2.93	5.68	2.35	3.38	3.34	5.33	5.23	40.83
1917	4.41	2.40	4.41	3.00	3.59	9.89	4.26	6.70	1.35	6.78	1.98	3.74	52.51
1918	3.10	3.03	1.94	1.80	4.08	3.45	7.73	2.28	6.23	6.03	5.25	3.24	48.16
1919	3.06	2.68	4.59	3.74	4.07	2.60	4.01	3.47	3.32	4.24	5.09	1.95	42.82
1920	1.97	6.85	3.37	7.56	1.91	2.75	3.64	3.95	8.05	1.89	3.72	8.03	53.69
Av. 21 yrs.	3.50	3.18	3.69	3.16	3.23	3.57	4.05	3.54	3.89	3.98	3.53	3.76	43.08

RAINFALL AT ORONO, ME. Elevation, 129 feet.

(Maine State College Agricultural Experiment Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.36	2.52	2.72	4.71	1.58	3.92	2.84	3.05	3.03	3.33	1.69	1.20	34.95
1915	2.49	3.56	0.34	3.30	4.97	2.47	6.67	4.67	1.19	2.62	3.04	3.57	38.89
1916	2.59	2.61	2.45	3.63	4.42	4.99	4.39	2.27	4.60	1.85	1.60	5.50	40.90
1917	4.11	3.67	3.22	2.39	3.18	7.49	4.05	4.09	1.08	5.89	1.55	3.24	43.96
1918	3.55	2.91	1.65	2.20	1.69	2.41	6.89	2.58	4.29	5.47	2.33	4.23	40.20
1919	3.45	1.10	2.92	2.29	3.08	1.44	4.07	0.92	3.07	2.31	2.61	1.42	28.68
1920	2.55	7.75	2.92	4.47	1.53	2.16	3.36	2.19	5.71	2.37	2.68	2.81	40.50
Av. 51 yrs.	3.88	3.61	3.86	2.90	3.34	3.31	3.47	3.34	3.50	3.84	3.64	3.52	42.21

RAINFALL AT PATTEN, ME. Elevation, 550 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.10	1.50	3.20	1.40	1.00	4.08	2.55	1.00	1.90	1.98	2.50	1.20	24.41
1915	2.50	3.60	0.30	2.90	3.90	2.30	6.30	4.20	2.80	4.20	2.30	2.40	37.70
1916	0.70	2.40	1.50	1.54	2.80	2.80	6.20	2.80	2.60	4.70	3.80	4.90	36.74
1917	2.40	1.80	3.60	2.00	5.20	8.90	3.60	3.84	0.00	8.20	1.20	3.50	44.24
1918	2.10	2.60	0.30	1.00	2.80	2.80	9.60	2.50	6.00	2.85	2.70	3.20	38.45
1919	2.40	2.50	3.40	3.30	6.80	1.20	...	...	...	...	...	...	....
Av. 16 yrs.	2.71	2.63	2.32	2.35	3.28	3.87	4.44	3.59	3.94	4.24	2.77	2.59	38.73

RAINFALL AT PORTLAND, ME. Elevation 99 feet..

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.19	3.92	4.37	4.42	2.02	2.34	3.10	3.81	0.73	2.05	3.17	2.98	36.10
1915	6.00	3.69	0.09	3.43	2.05	1.72	10.84	5.87	0.62	1.49	2.77	4.87	43.44
1916	2.15	4.30	5.22	5.56	5.64	6.32	3.82	2.14	1.47	1.29	2.83	6.09	46.83
1917	4.53	3.35	4.53	2.93	3.19	10.86	1.92	4.78	0.32	4.09	0.82	4.22	45.54
1918	3.48	2.62	1.93	2.71	1.76	2.73	2.94	4.64	5.58	2.39	3.38	4.30	38.46
1919	4.69	2.34	4.02	2.20	5.16	1.71	1.26	1.85	3.68	3.49	4.71	1.78	37.25
1920	3.49	8.97	5.53	7.04	3.23	2.73	3.67	3.83	8.16	1.12	5.87	6.05	59.69
Av. 50 yrs.	3.70	3.73	3.85	3.26	3.42	3.25	3.37	3.40	3.25	3.31	3.58	3.74	41.86

RAINFALL AT PRESQUE ISLE, ME.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	2.69	1.28	3.28	1.41	3.53	1.20	5.18	3.01	2.01	3.99	0.71	3.59	31.88
1914	2.95	2.70	2.50	4.05	2.74	4.80	2.23	2.35	2.10	2.75	3.50	2.10	34.77
1915	2.75	4.10	1.40	3.13	4.05	1.95	3.40	3.50	3.25	1.75	2.19	4.05	35.52
1916	2.20	2.35	1.10	1.75	3.44	2.17	3.68	1.70	4.04	2.37	2.85	5.90	33.55
1917	4.00	2.20	2.70	2.40	3.90	7.67	2.56	5.32	1.41	6.13	1.35	1.70	41.34
1918	2.40	3.80	1.80	1.65	4.00	**3.70**	**3.30**	1.62	**4.84**	**3.89**	**2.26**	**2.64**	35.90
1919	2.35	3.02	2.94	**2.38**	3.32	1.26	3.80	1.75	4.56	2.92	2.17	1.10	31.57
1920	1.49	4.00	1.96	5.31	0.91	6.08	4.28	3.62	5.21	5.35	1.35	4.00	43.56
Av. 8 yrs.	2.60	2.93	2.21	2.76	3.24	3.60	3.55	2.86	3.43	3.64	2.05	3.14	36.01

RAINFALL AT RUMFORD FALLS, ME. Elevation, 505 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.98	1.42	4.78	4.95	1.75	2.16	3.74	5.02	1.13	1.92	2.64	2.09	33.58
1915	3.82	4.65	0.21	3.48	0.78	2.46	8.38	5.84	1.84	1.79	2.30	3.47	39.02
1916	1.33	4.11	1.88	3.98	5.87	6.97	3.76	6.36	4.35	1.96	3.58	3.30	47.45
1917	3.36	1.15	3.35	2.77	2.85	10.40	1.94	7.20	1.33	5.24	1.06	3.26	43.91
1918	2.77	1.99	1.39	2.23	3.30	4.30	3.76	2.62	7.74	5.30	3.09	2.72	41.21
1919	2.72	1.50	5.10	1.99	3.94	1.74	1.42	2.41	3.98	5.57	4.19	1.24	35.80
1920	1.37	5.16	4.70	6.63	1.94	2.55	4.48	3.59	6.85	1.40	4.70	9.06	52.43
Av. 27 yrs.	2.95	3.15	3.43	3.18	3.42	3.50	3.84	3.61	3.55	3.20	3.24	3.06	40.13

RAINFALL AT VAN BUREN, ME. Elevation, 510 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.93	1.45	1.65	2.64	2.19	5.15	2.63	4.16	4.07	3.43	2.09	1.39	32.78
1915	1.31	4.22	1.56	1.99	5.14	1.08	4.36	2.99	4.75	2.44	2.06	3.79	35.69
1916	2.69	2.20	1.80	1.40	4.85	2.25	7.34	1.69	3.33	3.27	3.36	5.61	39.79
1917	3.39	2.01	3.93	2.53	2.18	7.86	2.74	6.02	1.77	5.28	1.81	0.76	40.28
1918	2.75	3.07	2.17	1.69	3.57	5.41	3.73	0.71	4.53	3.40	2.47	3.50	37.00
1919	3.03	2.63	2.88	2.00	2.55	3.08	...	...	...	...	..	2.25	....
1920	2.17	4.11	...	...	...	2.81	4.53	4.28	5.50	5.55	2.79	4.97	....
Av. 12 yrs.	2.38	2.56	2.55	1.93	3.30	3.80	3.88	3.29	3.13	3.36	1.98	2.91	35.07

RAINFALL AT WINSLOW, ME. Elevation, 90 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.44	1.34	4.00	5.14	1.12	2.07	1.07	4.88	0.95	2.49	1.52	1.77	27.79
1915	2.98	4.35	0.18	2.70	2.95	2.09	9.16	4.35	1.48	3.15	1.94	3.40	38.73
1916	1.07	2.83	0.94	2.72	3.67	3.35	3.69	4.41	3.78	3.17	5.11	4.12	38.86
1917	2.88	1.61	3.44	2.09	2.17	8.23	0.68	5.23	1.31	5.14	0.98	2.37	36.13
1918	1.78	2.37	0.74	1.74	1.83	2.15	6.06	3.42	6.66	4.84	3.26	2.96	37.81
1919	3.36	1.42	3.93	2.27	4.15	1.93	2.80	1.79	4.41	4.18	3.63	1.23	35.10
1920	0.79	5.62	3.05	7.54	1.89	2.26	4.20	2.35	9.40	1.51	3.95	5.30	47.86
Av. 25 yrs.	2.87	2.58	3.42	2.86	3.02	2.96	3.76	3.34	3.60	3.31	2.90	2.82	37.44

NEW HAMPSHIRE.

RAINFALL AT ALSTEAD, N. H. Elevation, 1 120 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.04	1.31	4.05	4.92	2.06	2.28	3.17	5.35	0.37	2.25	2.08	1.73	31.61
1915	3.97	3.93	0.40	2.94	1.55	1.67	11.07	8.14	1.90	2.85	1.77	4.68	44.87
1916	1.28	3.63	2.47	3.13	3.20	6.26	4.13	5.33	6.54	1.40	3.07	2.27	42.71
1917	2.80	1.40	2.67	1.92	3.49	8.19	2.72	4.00	0.55	6.55	0.59	2.42	37.30
1918	2.43	1.84	1.82	2.54	4.80	3.61	1.56	3.89	8.55	2.09	2.47	2.74	38.34
1919	2.18	1.81	4.60	1.79	6.67	2.10	2.38	4.37	6.36	2.91	5.26	1.56	41.99
1920	1.37	3.11	3.59	6.87	2.16	3.48	3.25	5.59	5.91	1.73	3.88	5.40	46.34
Av. 27 yrs.	2.70	2.76	3.37	3.00	3.28	3.33	4.12	4.35	3.96	3.06	3.06	3.14	40.13

RAINFALL AT BERLIN, N. H. Elevation, 1 090 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	...	...	...	...	...	...	...	...	...	5.90	0.41	4.18	....
1918	3.09	3.67	2.03	1.79	1.98	3.08	2.24	4.13	6.03	5.08	2.62	2.83	38.57
1919	2.49	1.05	4.65	1.81	2.51	2.27	1.44	2.39	4.21	5.29	4.82	1.42	34.35
1920	1.87	4.31	5.24	3.86	0.74	2.48	3.18	4.13	5.44	1.41	4.64	5.71	43.01
Av 3 yrs.	2.48	3.01	3.97	2.49	1.74	2.61	2.29	3.55	5.23	3.93	4.02	3.32	38.64

RAINFALL AT BETHLEHEM, N. H. Elevation, 1 470 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.93	1.61	3.24	6.10	1.16	3.27	3.37	4.39	2.34	1.11	2.39	0.65	31.56
1915	1.87	3.26	0.47	3.26	1.82	2.80	7.16	3.39	2.36	1.73	1.66	3.70	33.48
1916	1.69	3.07	3.28	2.39	3.48	6.32	6.02	3.23	5.25	1.19	3.71	2.84	42.47
1917	2.36	1.31	2.66	2.43	2.00	7.02	2.39	5.02	1.49	5.60	0.60	2.15	35.03
1918	1.83	1.90	1.28	1.71	3.56	3.12	1.72	4.11	7.91	6.14	2.06	3.29	38.63
1919	2.27	1.66	4.77	3.32	2.39	2.26	1.88	2.81	4.67	4.81	5.11	1.79	37.74
1920	2.40	3.75	4.18	5.40	1.43	2.86	3.52	2.44	6.35	0.95	2.85	5.23	41.36
Av. 28 yrs.	2.31	2.38	3.03	2.68	3.13	3.77	4.02	3.80	4.01	3.09	2.66	2.57	37.45

RAINFALL AT BROOKLINE, N. H. Elevation, 250 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.75	2.88	5.26	4.81	2.33	1.83	3.49	2.49	0.45	1.35	2.38	3.16	33.18
1915	4.95	3.60	0.02	2.48	1.61	2.29	8.91	7.04	1.19	2.98	3.46	3.80	42.33
1916	1.56	5.30	3.50	4.80	4.47	6.48	4.93	2.61	4.19	1.44	3.11	2.92	45.31
1917	3.35	2.87	3.68	2.48	3.93	5.57	1.48	4.76	0.62	5.36	1.00	5.17	40.27
1918	2.01	2.08	1.70	4.10	1.43	**3.54**	**2.58**	**2.59**	**7.06**	**1.24**	**2.46**	**3.26**	34.05
Av. 26 yrs.	2.98	3.43	3.84	3.66	3.36	3.54	3.66	3.82	3.45	3.53	3.13	3.49	41.89

RAINFALL AT CONCORD, N. H. Elevation, 350 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.75	1.65	3.90	3.87	1.54	2.39	3.49	5.91	0.21	1.12	2.28	2.07	31.18
1915	3.47	2.89	T	2.62	0.99	1.37	10.29	6.26	1.21	3.02	2.97	3.42	38.51
1916	1.22	4.18	3.01	2.96	3.95	6.26	4.55	3.45	4.37	1.34	2.63	2.21	40.13
1917	3.35	1.50	2.03	1.63	2.92	8.30	1.27	4.72	0.57	3.54	0.85	2.32	33.00
1918	1.65	1.82	1.26	2.26	2.43	2.77	1.74	3.97	6.96	1.14	2.34	3.52	31.86
1919	3.05	1.94	3.28	1.92	5.11	1.64	1.47	1.60	3.07	2.71	3.98	0.99	30.76
1920	1.46	3.23	2.43	5.91	2.50	3.68	3.24	4.77	7.91	0.98	2.62	5.80	44.53
Av. 64 yrs.	3.03	2.79	3.19	2.90	3.17	3.22	3.66	3.82	3.38	3.39	3.25	3.09	38.89

RAINFALL AT DURHAM, N. H. Elevation, 88 feet.

(N. H. Agricultural College.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.48	2.21	4.22	5.89	1.22	1.42	3.27	3.46	0.19	1.32	2.24	3.14	31.06
1915	3.98	2.84	0.05	1.75	1.47	2.08	11.22	6.18	0.85	1.84	3.61	3.85	39.72
1916	0.60	2.36	2.20	5.29	7.78	6.79	3.61	1.69	4.02	1.41	2.77	4.95	43.47
1917	3.16	1.81	2.31	1.45	4.10	7.52	1.28	4.23	0.43	7.09	0.73	2.37	36.48
1918	2.05	1.90	1.21	1.37	2.41	2.74	5.24	3.25	6.43	0.73	1.39	2.49	31.21
1919	2.81	2.46	3.85	2.33	4.66	1.87	1.61	2.16	5.36	2.79	5.20	1.65	36.75
1920	1.75	4.33	3.27	5.82	3.65	4.04	2.77	3.52	8.82	1.35	5.28	5.01	49.61
Av. 26 yrs.	3.38	3.00	3.25	3.13	3.13	3.42	3.35	3.31	3.92	3.09	2.84	3.49	39.31

RAINFALL AT FRANKLIN, N. H. Elevation, 440 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.67	1.81	4.67	5.76	1.53	3.08	3.26	8.50	0.50	1.27	2.45	2.89	38.39
1915	4.47	4.26	0.06	3.29	0.83	1.17	11.70	7.23	1.67	2.83	3.09	3.69	44.29
1916	1.58	4.07	3.09	3.53	4.56	9.04	4.33	3.51	6.09	1.60	3.56	3.04	48.00
1917	3.73	1.73	3.16	2.65	3.21	7.51	2.92	3.46	0.87	4.89	1.03	3.86	39.02
1918	3.14	2.34	2.31	2.32	1.84	3.68	2.95	3.92	8.25	2.74	2.34	3.25	39.08
1919	2.57	1.79	4.24	1.59	6.36	2.22	2.59	2.75	2.97	3.44	5.54	1.25	37.31
1920	1.57	4.08	3.67	5.93	2.58	2.88	3.85	5.50	8.18	1.33	3.67	6.47	49.71
Av. 19 yrs.	2.95	2.88	3.33	3.20	3.11	3.78	3.72	3.97	4.18	2.92	2.73	3.13	39.90

RAINFALL AT HANOVER, N. H. Elevation, 603 feet.

(Dartmouth College.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.31	1.72	4.35	5.77	1.82	1.90	2.67	3.62	1.08	1.17	2.29	1.54	30.24
1915	3.32	3.92	0.03	1.81	0.98	2.50	9.69	4.81	1.59	1.82	1.93	4.35	36.75
1916	1.29	3.34	3.01	3.06	3.57	5.42	3.54	2.85	4.96	1.04	2.44	2.41	36.93
1917	2.03	1.11	2.40	2.02	2.29	6.67	1.48	3.76	0.87	5.49	0.55	2.12	30.79
1918	2.21	1.85	1.44	2.41	3.54	4.04	1.59	4.53	6.18	2.92	1.56	2.25	34.52
1919	1.84	1.23	3.41	1.74	5.56	1.70	2.17	3.88	4.88	4.04	4.15	1.62	36.22
1920	2.69	3.76	3.39	6.02	3.85	2.39	3.34	3.21	6.09	1.47	5.26	4.68	46.15
Av. 75 yrs.	2.71	2.44	2.67	2.41	3.29	3.53	3.43	3.48	3.21	3.17	2.80	2.70	35.84

RAINFALL AT KEENE, N. H. Elevation, 506 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.33	1.72	4.05	4.54	1.70	2.49	2.34	5.08	0.25	1.41	1.80	1.76	29.47
1915	4.44	4.36	0.04	2.61	1.11	1.64	11.09	5.51	2.44	2.71	2.25	5.61	43.81
1916	1.57	3.84	2.78	3.29	3.25	5.70	4.48	3.27	6.00	1.27	3.71	2.64	41.80
1917	3.41	2.28	2.97	1.63	2.94	5.79	2.27	5.38	0.74	5.62	0.52	3.40	36.95
1918	2.78	2.16	1.95	2.84	5.18	3.69	2.53	2.64	7.01	1.52	2.21	3.39	37.90
1919	2.15	1.81	4.93	1.82	5.93	1.03	2.26	3.87	4.69	2.72	4.95	1.53	37.69
1920	1.77	5.04	4.21	5.90	2.75	2.87	3.89	6.27	5.19	1.46	3.73	5.22	48.30
Av. 29 yrs.	2.66	2.79	3.16	2.68	3.20	2.99	3.80	4.16	3.61	2.76	2.72	3.06	37.59

RAINFALL AT LAKEPORT, N. H. Elevation, 500 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.14	2.14	5.75	5.75	1.45	2.81	4.67	4.35	0.24	1.04	3.00	2.96	37.30
1915	4.74	4.67	0.07	3.35	0.83	1.52	12.56	9.46	1.36	2.47	2.80	3.76	47.59
1916	1.90	4.35	3.57	3.83	4.01	8.02	4.57	2.35	4.13	1.54	3.42	3.62	45.31
1917	3.65	2.05	3.82	3.56	2.79	7.81	2.00	5.28	0.43	4.32	0.80	4.32	40.83
1918	3.25	2.50	2.24	2.43	2.38	3.42	2.07	4.06	7.29	2.81	2.51	4.26	39.22
1919	2.92	2.52	4.50	1.94	6.12	2.38	2.47	1.71	3.08	4.10	5.60	1.29	38.63
1920	2.16	7.75	5.14	6.32	2.64	3.12	3.56	3.71	8.40	0.80	4.33	3.75	51.68
Av. 64 yrs.	3.53	3.48	3.84	3.12	3.25	3.21	3.88	3.62	3.64	3.49	3.65	3.55	42.26

RAINFALL AT MANCHESTER, N. H. Elevation, 200 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.62	2.04	4.54	4.78	2.20	1.86	3.93	3.15	0.12	0.72	2.30	2.95	31.21
1915	3.61	2.93	0.00	1.39	2.44	2.06	11.40	7.18	0.71	2.67	2.77	3.36	40.52
1916	1.25	4.75	2.45	3.76	3.73	5.71	4.06	5.41	4.98	1.09	2.88	3.25	43.32
1917	3.00	2.36	3.17	1.82	3.67	7.58	2.37	3.65	1.09	4.06	0.84	3.10	36.71
1918	2.67	1.72	2.19	2.39	1.71	2.69	2.62	4.37	6.36	0.93	2.85	3.24	33.74
1919	3.43	2.48	4.65	2.13	5.66	1.60	2.72	1.45	3.93	2.30	6.90	1.36	58.61
1920	1.83	4.82	4.13	6.24	3.24	4.25	2.58	6.91	7.52	1.58	3.77	6.08	52.95
Av. 46 yrs.	3.20	3.11	3.57	2.92	3.15	2.96	3.39	3.38	3.28	3.02	3.21	3.28	38.47

RAINFALL AT MERRIMAC, N. H. Elevation, 120 feet.
(Thornton's Ferry.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.30	2.56	3.68	5.50	2.16	1.76	2.84	2.11	0.22	0.88	2.09	2.62	28.72
1915	4.10	2.63	0.00	2.07	2.06	2.20	8.24	5.05	0.83	2.14	2.30	3.89	35.51
1916	1 32	5.29	2.63	4.59	4.31	5.85	3.16	3.40	3.08	1.25	2.84	4.22	41.91
1917	2.61	2.18	3.58	1.79	2.89	5.80	2.64	4.57	0.48	3.37	0.95	3.21	34.07
1918	2.86	2.41	1 90	2.03	1.16	2.69	2.22	1.98	6.68	0.48	2.86	2.73	30.00
1919	3.60	2.68	5.31	1.66	5.81	0.37	0.34	2.21	2.65	1.58	5.29	1.13	32.63
1920	0.31	2.31	3.18	4.49	3.04	3.89	1.56	2.37	8.42	0.43	4.41	5.60	40.01
Av. 7 yrs.	2.44	2.87	2.90	3.16	3.06	3.22	3.00	3.10	3.19	1.45	2.96	3.34	34.69

RAINFALL AT NASHUA, N. H. Elevation, 125 feet.
(Nashua Mfg. Co., Jackson Mills.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.85	3.01	4.93	5.34	2.43	1.42	4.31	3.10	0.19	1.03	2.78	2.62	34.01
1915	4.36	1.95	T	1.69	2.06	1.24	8.89	5.72	0.99	2.66	2.63	3.69	35.79
1916	1.13	3.32	3.21	4.38	5.02	7.57	3.20	2.66	**3.09**	1.01	**2.50**	**2.87**	39.96
1917	2.96	2.58	3.67	2.02	3.47	5.06	1.85	3.80	0.82	3.97	1.00	3.30	34.50
1918	3.15	2.45	2.19	2.47	1.58	2.93	2.97	1.96	7.74	0.64	2.57	2.81	33.46
1919	2.60	2.94	4.20	1.86	4.31	1.65	1.21	0.91	4.80	1.65	4.32	1.12	31.57
1920	1.76	5.23	3.95	6.73	2.91	4.29	3.30	1.80	8.96	0.60	4.15	5.35	49.03
Av. 37 yrs.	3.47	3.63	3.79	3.16	3.22	2.91	3.42	3.67	3.32	2.99	3.13	3.53	40.24

RAINFALL AT NEWTON, N. H. Elevation, 200 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.84	1.86	4.13	7.16	2.53	1.38	2.89	2.94	0.17	1.00	2.77	2.98	32.65
1915	4.23	2.38	0.16	1.92	1.42	1.88	11.47	7.42	0.20	2.57	3.22	3.79	40.66
1916	1.48	4.22	2.57	4.69	5.26	7.30	3.76	2.97	**3.00**	1.14	2.55	2.71	41.65
1917	2.85	1.89	3.05	2.83	3.63	5.87	1.31	3.94	0.88	6.32	1.14	2.69	36.40
1918	2.58	2.09	1.80	2.38	1.82	3.31	4.00	3.11	7.04	1.24	2.80	**2.27**	34.44
Av. 29 yrs.	3.22	3.12	3.45	3.33	3.27	3.15	3.46	3.30	3.25	3.48	3.09	3.19	39.31

RAINFALL AT PITTSBURG, N. H. Elevation, 1 575 feet.
(First Connecticut Lake.) (Connecticut Valley Lumber Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1918	1.38	2.04	1.74	1.57	4.01	3.10	4.24	2.99	6.97	8.74	4.05	4.45	45.28
1919	3.46	1.95	3.16	3.72	2.80	2.65	4.23	4.63	6.59	7.13	3.22	1.80	45.34
1920	2.04	2.93	3.56	4.45	1.11	5.83	8.19	3.22	7.14	2.52	2.75	6.72	50.46
Av. 3 yrs.	2.29	2.31	2.82	3.25	2.64	3.86	5 55	3.61	6.90	6.13	3.34	4.32	47.02

RAINFALL AT PITTSBURG, N. H. Elevation, 1 575 feet.
(Second Connecticut Lake.) (Connecticut Valley Lumber Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1918	1.38	4.62	3.42	1.34	5.01	4.27	5.13	2.43	7.65	8.33	3.81	4.31	51.70
1919	3.42	1.58	2.65	2.19	3.80	1.93	4.67	4.96	5.62	7.52	3.35	2.04	43.73
1920	2.10	3.09	3.70	5.24	0.93	6.20	8.18	3.78	7.34	3.45	3.22	7.75	54.98
Av. 3 yrs.	2.30	3.10	3.26	2.92	3.25	4.13	5.99	3.72	6.87	6.43	3.46	4.70	50.13

RAINFALL AT PLYMOUTH, N. H. Elevation, 500 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.22	1.23	1.20	6.09	1.04	3.16	4.42	4.23	0.51	1.61	2.75	2.20	33.66
1915	3.94	4.95	0.16	2.18	1.36	2.71	8.71	6.29	2.09	2.30	2.33	3.20	40.22
1916	1.77	3.60	1.97	2.27	3.88	6.02	6.22	3.43	5.20	1.47	3.55	2.14	41.52
1917	3.61	1.42	3.47	2.37	2.36	7.27	2.04	3.38	0.67	5.60	0.83	1.94	34.96
1918	1.95	2.46	1.26	2.09	2.30	4.00	2.44	4.10	7.57	3.28	2.42	3.17	37.04
1919	2.27	1.50	4.68	1.66	6.01	2.66	2.47	3.30	4.78	4.98	4.97	1.29	40.57
1920	1.65	3.06	3.36	6.92	2.54	2.76	4.55	3.79	7.05	1.41	4.08	6.83	48.00
Av. 33 yrs.	3.05	2.90	3.43	2.78	3.24	3.40	3.78	3.95	3.87	3.21	3.08	3.09	39.78

RAINFALL AT STEWARTSTOWN (WEST), N. H. Elevation, 1 050 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.07**	**1.14**	**2.28**	1.86	0.99	2.64	3.32	2.75	4.32	2.08	2.09	0.98	26.52
1915	1.21	2.01	0.19	**2.11**	0.81	3.18	8.10	6.94	2.76	2.49	1.03	2.41	33.24
1916	1.47	1.72	1.43	1.89	3.79	5.34	3.22	4.01	3.71	1.95	2.41	1.61	32.55
1917	2.77	1.40	1.93	1.97	1.12	5.46	1.77	7.50	1.15	5.77	0.53	1.70	33.07
1918	1.84	1.23	3.43	0.37	2.27	3.44	3.48	1.26	6.03	5.78	2.13	2.00	33.26
1919	1.91	3.13	2.81	1.97	2.12	3.29	2.15	3.87	5.05	5.45	2.90	0.83	35.48
1920	2.08	2.73	2.10	4.48	0.98	3.67	4.61	2.48	3.12	3.31	2.23	2.17	33.96
Av. 7 yrs.	1.91	1.91	2.02	2.09	1.73	3.86	3.81	4.12	3.73	3.83	1.90	1.67	32.58

RAINFALL AT WARREN (GLEN CLIFF), N. H. Elevation, 1 650 feet.
(Benton, N. H., record prior to 1914.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.08**	**1.42**	1.95	11.18	0.90	1.94	4.42	3.27	1.58	1.15	3.80	1.81	35.50
1915	**2.90**	3.89	0.72	2.74	1.84	2.95	8.70	5.23	1.90	2.30	3.04	4.66	40.87
1916	1.99	3.70	2.01	3.75	3.93	5.33	3.67	4.35	5.22	3.19	3.63	4.04	44.81
1917	2.69	2.17	5.19	3.16	3.69	7.76	2.77	2.84	1.68	6.81	0.73	2.15	41.64
1918	2.61	2.56	2.26	2.03	4.17	4.19	2.06	6.30	6.96	5.88	2.57	3.29	44.88
1919	2.27	1.66	4.77	2.09	3.83	2.96	2.73	3.32	6.64	5.00	4.77	1.43	41.47
1920	2.15	5.38	3.42	5.54	2.46	2.98	3.63	3.81	6.36	1.02	4.75	5.15	46.65
Av. 11 yrs.	2.54	2.68	3.07	3.61	3.30	3.44	3.99	4.10	4.02	3.69	3.16	3.07	40.67

VERMONT.

RAINFALL AT BELLOWS FALLS, VT. Elevation, 300 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.18**	**1.52**	**4.05**	4.38	1.50	2.01	2.30	4.74	0.56	1.31	1.32	1.58	27.45
1915	4.58	3.82	0.07	1.86	1.64	1.20	9.34	8.47	1.47	2.34	2.81	3.90	41.50
1916	1.04	4.54	2.53	3.00	2.68	4.01	3.53	2.29	5.55	1.27	2.83	1.69	34.96
1917	2.60	1.74	2.77	1.21	2.33	6.20	1.28	2.85	0.35	6.11	0.77	1.53	29.74
1918	3.02	2.30	1.91	2.66	4.63	4.04	0.68	3.31	7.40	1.61	2.12	2.36	36.04
1919	2.10	2.72	4.81	1.83	6.83	1.27	2.25	3.53	3.65	1.62	4.36	2.03	37.00
1920	1.51	2.69	2.53	6.63	2.58	1.70	3.59	2.35	3.68	4.48	3.88	5.39	41.01
Av. 7 yrs.	2.43	2.76	2.67	3.08	3.17	2.92	3.28	3.93	3.24	2.68	2.58	2.64	35.38

RAINFALL AT BLOOMFIELD, VT. Elevation, 900 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.37	0.90	2.52	3.88	0.89	3.07	3.54	3.20	2.99	1.12	1.84	1.18	26.50
1915	2.01	3.73	0.41	1.99	1.82	3.11	11.93	5.94	3.31	2.29	1.67	2.73	40.94
1916	1.82	2.11	0.80	2.56	3.26	5.62	5.29	4.16	4.73	2.01	4.58	1.77	38.71
1917	2.94	1.29	2.86	1.79	1.62	5.84	3.38	7.64	2.24	7.08	0.45	1.83	38.96
1918	1.52	2.86	1.28	1.28	4.50	4.69	2.59	4.53	8.03	8.20	2.71	2.91	45.10
1949	2.37	1.30	3.03	3.60	2.76	4.71	2.47	3.03	5.38	7.36	3.29	1.41	40.71
1920	1.53	2.35	2.65	5.91	1.62	1.63	10.02	3.20	5.09	1.85	3.49	5.62	44.96
Av. 14 yrs.	2.18	2.03	2.33	2.82	2.95	4.00	5.67	4.17	4.22	3.55	2.25	2.39	38.56

RAINFALL AT BURLINGTON, VT. Elevation, 404 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.60	0.41	1.84	4.27	0.36	3.30	1.94	2.78	2.36	1.10	1.41	1.25	22.62
1915	1.16	3.28	0.22	0.73	1.73	2.18	5.46	2.88	0.97	2.74	1.72	2.61	25.68
1916	0.87	2.32	1.31	1.85	4.69	4.32	1.67	1.06	4.06	1.43	2.08	2.79	28.45
1917	2.18	1.60	2.99	2.42	2.00	3.69	1.88	3.52	3.62	5.76	0.95	1.10	31.71
1918	1.73	1.79	1.86	1.67	4.92	4.52	2.95	4.01	5.67	6.75	4.53	1.78	42.18
1919	1.18	1.02	3.32	2.42	3.54	1.61	1.47	2.91	3.40	6.02	2.10	1.08	30.10
1920	1.29	1.74	3.38	5.83	1.74	4.01	4.85	2.37	5.94	1.76	2.88	5.29	41.08
Av. 86 yrs.	1.82	1.65	2.04	2.07	3.05	3.40	3.87	3.42	3.60	3.28	2.51	1.96	32.67

RAINFALL AT CAVENDISH, VT. Elevation, 910 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.08	2.56	3.57	2.84	1.09	2.70	5.47	6.17	0.62	1.60	1.76	2.95	33.41
1915	4.89	4.22	T	2.18	1.30	2.85	10.55	5.91	1.80	2.78	3.27	3.81	43.56
1916	2.06	2.46	4.32	4.59	3.12	5.73	2.79	1.30	5.23	1.45	3.62	1.84	38.51
1917	3.04	2.16	2.87	2.80	4.24	4.56	1.52	2.08	0.87	5.37	1.16	4.57	35.24
1918	3.44	1.34	1.08	2.98	3.46	4.29	3.84	2.52	7.14	2.20	3.24	1.62	37.15
1919	1.24	2.14	4.98	1.67	6.71	2.02	3.36	4.19	4.46	2.72	4.80	1.70	39.99
1920	1.45	4.54	3.55	6.59	2.25	3.14	2.60	3.49	4.24	2.69	5.89	5.94	46.37
Av. 17 yrs.	2.47	2.40	2.64	2.64	3.43	3.14	3.78	3.43	4.13	2.98	2.70	2.69	36.43

RAINFALL AT CHELSEA, VT. Elevation, 840 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.50	2.02	4.42	**5.41**	0.65	1.96	2.60	3.94	1.82	1.20	2.48	1.36	29.36
1915	2.80	3.38	0.20	1.63	2.05	2.23	5.73	4.19	1.78	1.52	1.65	2.92	30.08
1916	1.73	2.96	1.53	2.25	3.69	5.10	2.39	1.91	4.87	1.36	2.69	2.21	32.69
1917	2.21	0.94	2.29	**2.04**	2.23	4.81	2.52	5.16	1.51	5.67	0.76	2.35	32.49
1918	1.70	1.37	1.89	1.95	3.20	2.97	2.25	4.25	5.18	4.40	2.27	2.32	33.75
1919	1.45	1.76	4.42	1.92	4.36	2.21	1.40	2.85	5.60	3.28	3.30	1.32	33.87
1920	1.51	2.81	3.89	6.23	1.37	3.59	3.24	1.75	4.69	2.29	4.72	5.22	41.31
Av. 35 yrs.	2.68	2.64	2.95	2.38	3.09	3.21	3.40	3.65	3.38	2.68	2.81	2.61	35.48

RAINFALL AT CORNWALL, VT. Elevation, 507 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.16	1.30	1.44	5.31	1.02	2.35	4.43	5.28	1.72	1.47	2.52	1.24	29.24
1915	1.90	2.40	0.17	0.63	1.44	1.70	3.96	3.43	0.77	2.51	2.18	2.87	23.96
1916	1.24	2.48	2.15	1.82	2.81	3.61	2.17	1.38	3.36	1.73	1.69	1.84	26.28
1917	1.87	1.08	2.51	1.95	2.08	3.72	2.15	3.56	1.86	6.60	0.69	1.42	29.49
1918	1.57	1.76	2.17	1.25	3.76	3.40	2.85	3.57	7.03	5.11	3.69	1.36	37.52
1919	1.05	0.73	1.65	1.47	2.97	3.25	3.26	2.67	3.70	3.25	3.66	1.05	28.71
1920	1.48	3.60	2.86	5.59	1.10	2.05	4.44	3.60	4.95	2.58	3.12	4.54	39.91
Av. 34 yrs.	2.11	2.07	2.15	1.98	2.85	3.32	3.44	3.35	3.18	2.73	2.49	2.17	31.84

RAINFALL AT ENOSBURG FALLS, VT. Elevation, 601 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.78	0.47	1.74	3.79	0.64	3.22	3.63	4.94	3.99	2.34	2.48	1.43	30.45
1915	1.71	3.76	0.64	1.36	2.89	2.56	5.21	2.07	2.65	3.43	2.77	3.83	32.88
1916	1.82	2.09	0.97	1.62	4.14	3.53	4.48	3.38	5.95	2.52	3.24	3.23	36.97
1917	2.33	1.54	1.13	2.27	2.38	4.21	6.62	4.44	3.41	7.09	0.99	1.51	37.92
1918	2.02	1.33	0.94	0.91	3.01	4.89	4.74	1.81	9.69	8.33	3.16	1.54	42.37
1919	1.32	0.91	3.36	4.10	3.36	5.12	2.38	6.12	4.87	7.50	2.55	0.88	42.47
1920	1.41	1.16	3.14	5.60	1.08	4.02	6.86	2.00	4.47	2.57	3.50	4.90	40.71
Av. 29 yrs.	2.47	2.53	2.84	2.53	3.45	4.21	4.77	3.70	3.82	3.57	3.11	2.80	39.80

RAINFALL AT GUILDHALL, VT. Elevation, 875 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**1.58**	**1.45**	**2.56**	1.59	0.75	2.86	3.36	5.66	2.72	0.56	1.61	0.50	25.20
1915	1.65	3.18	0.36	1.37	2.03	2.33	8.51	5.72	3.59	1.68	1.41	2.57	34.40
1916	1.85	1.88	0.99	1.75	3.74	4.69	5.11	5.35	4.08	1.74	3.01	1.89	36.08
1917	2.36	1.10	1.73	1.39	1.55	6.91	2.79	7.49	2.48	5.88	0.72	1.50	35.90
1918	1.45	2.18	1.64	0.82	2.21	3.41	3.42	3.84	6.82	7.17	2.21	1.52	36.72
1919	1.27	1.19	1.44	2.24	2.40	2.76	1.09	2.45	3.72	4.67	2.58	1.12	26.93
1920	1.53	1.96	2.10	4.00	1.25	1.06	5.19	1.73	4.56	2.72	1.59	1.81	29.50
Av. 7 yrs.	1.67	1.85	1.54	1.88	1.99	3.43	4.21	4.60	4.00	3.49	1.88	1.56	32.10

RAINFALL AT HALIFAX, VT. Elevation, 900 feet.
(Mays Mills.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.94**	**2.14**	**3.62**	3.27	0.79	0.06	1.63	4.19	0.21	1.39	2.13	2.02	24.39
1915	3.92	1.71	0.00	1.58	0.78	0.37	10.50	6.49	**2.09**	1.95	2.11	7.42	38.90
1916	2.35	6.24	4.70	3.34	3.59	2.96	4.98	2.69	5.86	0.78	5.01	2.82	45.32
1917	3.87	2.18	3.97	1.99	4.60	4.77	1.83	2.99	1.07	7.30	1.00	3.64	39.21
1918	3.86	2.75	1.29	2.45	3.08	1.92	1.66	2.53	6.35	1.12	2.47	3.14	32.62
1919	1.98	2.41	4.95	1.60	7.71	1.24	2.54	4.11	4.63	3.14	5.11	1.90	41.32
1920	1.86	6.19	4.40	6.36	2.60	5.17	2.20	4.67	5.07	0.93	5.81	5.58	50.84
Av. 7 yrs.	2.97	3.37	3.27	2.94	3.31	2.36	3.62	3.95	3.61	2.37	3.38	3.79	38.94

RAINFALL AT HYDE PARK, VT. Elevation, 576 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.82	1.27	5.37	2.20	2.63	2.52	3.87	1.34	2.15	3.28	1.63	2.20	32.28
1914	1.90	1.32	2.58	4.72	0.52	4.36	6.12	5.45	3.36	1.52	2.92	1.55	36.32
1915	1.71	3.43	0.53	1.85	1.83	2.10	7.36	2.75	3.38	2.49	2.62	2.76	32.81
1916	1.70	2.09	1.36	2.63	3.23	5.30	2.61	2.74	4.65	2.84	3.38	2.68	35.21
1917	2.85	1.10	2.12	3.16	2.00	7.59	6.45	7.23	2.10	6.54	1.38	2.13	44.65
1918	2.47	2.30	2.01	1.43	5.56	4.37	4.79	2.42	6.98	6.59	2.75	**1.93**	43.60
Av. 6 yrs.	2.41	1.92	2.33	2.66	2.63	4.37	5.20	3.65	3.77	3.88	2.45	2.21	37.48

RAINFALL AT LONDONDERRY (SOUTH), VT. Elevation, 1 000 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.06**	**1.94**	**3.81**	5.24	1.72	2.11	3.92	5.29	0.27	0.21	2.44	1.89	30.90
1915	4.89	4.95	0.15	2.78	1.00	2.48	10.22	5.84	1.58	2.31	2.34	3.81	42.35
1916	2.38	4.75	3.28	3.58	2.89	3.69	3.33	3.25	3.76	1.62	3.78	2.53	38.84
1917	2.43	2.11	2.62	2.39	3.56	3.48	2.61	4.75	0.57	5.56	0.87	2.44	33.39
1918	2.47	3.02	1.97	2.50	2.63	4.12	1.63	2.64	6.40	2.04	1.52	2.52	33 46
1919	1.69	1.42	4.76	1.75	5.53	1.66	4.13	3.05	4.41	3.50	3.55	1.74	37.19
1920	1.09	2.41	1.84	5.27	1.50	2.93	3.08	5.32	2.59	3.11	6.37	3.40	38.91
Av. 7 yrs.	2.43	2.94	2.63	3.36	2.69	2.92	4.13	4.31	2.80	2.62	2.98	2.62	36.43

RAINFALL AT LUNENBURG, VT. Elevation, 850 feet.
(Fitzdale.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**1.86**	**1.80**	**2.92**	2.95	0.91	2.53	3.94	5.02	2.08	0.72	1.03	0.24	26.00
1915	1.41	2.02	0.06	1.69	1.47	1.68	7.20	3.30	2.54	1.36	1.27	2.09	26.09
1916	1.90	0.88	1.35	1.14	3.36	6.47	3.79	4.38	4.58	1.46	2.49	3.59	35.39
1917	1.95	0.91	1.55	1.30	1.28	6.40	2.10	5.79	0.68	5.93	0.25	0.48	28.62
1918	1.15	**2.38**	0.40	1.57	3.25	2.73	2.02	3.44	8.01	8.15	2.11	1.59	36.80
1919	1.41	0.98	2.37	3.05	3.02	2.10	1.37	3.08	2.78	4.85	2.80	1.25	29.06
1920	1.56	1.81	1.90	4.46	1.30	3.00	4.90	2.44	1.74	0.93	4.75	5.67	34.46
Av. 7 yrs.	1.60	1.54	1.51	2.31	2.08	3.56	3.62	3.92	3.20	3.34	2.10	2.13	30.91

RAINFALL AT NORTHFIELD, VT. Elevation, 876 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.75	1.56	3.48	5.05	0.90	2.85	4.22	3.14	2.04	1.00	2.90	1.19	30.08
1915	2.56	3.32	0.25	1.06	1.56	3.16	5.22	4.55	1.36	1.72	1.43	2.76	28.95
1916	1.14	2.71	1.31	1.94	3.83	4.47	4.02	1.94	3.00	2.09	3.13	1.78	31.36
1917	3.20	0.74	2.18	2.05	2.28	5.40	3.08	3.13	1.37	5.82	1.04	1.84	32.13
1918	1.85	2.05	1.43	2.28	3.13	3.16	1.77	6.71	5.08	5.21	2.25	2.24	37.16
1919	1.02	1.47	5.42	1.39	4.26	2.47	1.54	2.40	2.88	3.47	2.36	1.29	29.97
1920	1.24	2.05	2.52	5.12	1.28	3.60	3.70	2.19	5.56	1.80	4.20	4.35	37.61
Av. 33 yrs.	2.31	2.26	2.65	2.23	2.87	3.11	3.43	3.54	3.01	2.73	2.53	2.45	33.12

RAINFALL AT NORWICH, VT. Elevation, 550 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.94	2.54	3.65	6.18	1.15	2.20	3.24	3.79	1.02	1.39	2.92	2.09	32.11
1915	3.32	3.10	0.10	1.95	1.04	2.42	9.54	5.24	2.02	1.74	2.31	3.18	35.96
1916	1.59	3.17	4.10	3.34	4.00	5.59	4.07	2.66	5.41	1.36	2.63	2.07	39.99
1917	3.64	1.24	2.20	2.14	2.63	5.15	1.88	4.18	1.05	5.41	0.64	2.85	33.01
1918	1.95	2.95	2.02	2.47	4.09	3.50	1.71	4.05	6.26	3.12	2.77	2.65	37.54
Av. 26 yrs.	2.73	2.78	3.04	2.54	3.30	3.38	3.75	3.46	3.54	2.94	2.50	2.86	36.82

RAINFALL AT READSBORO, VT. Elevation, 1 220 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	**3.68**	1.85	0.00	**1.84**	**1.12**	0.80	7.88	5.98	2.02	1.12	2.47	6.44	35.20
1916	3.33	4.83	4.87	3.50	4.03	5.02	5.98	1.82	4.71	2.20	4.80	3.36	48.45
1917	4.17	3.25	3.89	2.58	4.89	4.54	3.49	4.49	0.89	6.57	1.10	3.23	43.09
1918	3.07	3.77	3.07	3.20	4.24	4.61	3.50	2.68	7.41	3.08	2.81	4.51	45.95
1919	2.83	2.42	5.75	2.71	9.68	4.30	3.35	8.21	6.91	5.75	6.65	2.06	60.62
1920	2.20	3.94	3.81	7.32	3.19	7.81	3.55	4.81	4.60	4.66	6.32	6.30	58.51
Av. 6 yrs.	3.21	3.34	3.57	3.53	4.53	4.51	4.63	4.66	4.42	3.90	4.02	4.32	48.64

RAINFALL AT RUTLAND, VT. Elevation, 562 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	2.29	1.65	1.50	1.74	1.70	3.76	2.17	4.00	1.12	5.79	0.42	1.32	27.46
1918	2.07	2.13	1.44	1.94	4.40	3.85	2.93	2.48	6.76	3.68	2.46	2.43	36.57
1919	2.19	1.14	3.07	1.77	4.20	3.19	2.92	3.11	5.80	4.40	3.71	1.02	36.52
1920	1.52	1.64	2.48	5.72	1.77	2.30	4.48	3.62	3.07	4.29	4.83	3.27	38.99
Av. 4 yrs.	2.02	1.64	2.12	2.79	3.02	3.28	3.12	3.30	4.19	4.54	2.86	2.01	34.89

RAINFALL AT RYEGATE (EAST), VT. Elevation, 480 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**1.22**	**1.82**	**4.83**	4.88	0.50	1.32	3.69	4.36	1.87	0.79	2.67	0.52	28.47
1915	1.44	3.12	0.14	1.33	1.75	1.43	7.39	5.48	2.55	1.49	1.70	3.09	30.91
1916	2.19	2.55	1.80	2.27	3.66	4.44	3.01	2.71	3.96	0.97	3.83	2.41	33.80
1917	3.25	1.52	2.04	2.96	2.11	7.04	2.20	7.65	1.37	5.80	0.90	1.84	38.68
1918	2.21	3.28	1.71	1.31	2.97	2.73	3.36	4.11	6.92	6.34	1.48	2.60	39.02
1919	2.16	1.83	3.58	2.28	3.14	1.95	1.24	2.11	3.81	4.11	3.80	1.38	31.39
1920	2.33	3.64	2.58	5.71	2.08	2.00	3.84	4.33	4.67	2.77	3.67	4.87	42.49
Av. 7 yrs.	2.11	2.54	2.38	2.96	2.32	2.99	3.53	4.39	3.59	3.18	2.58	2.39	34.96

RAINFALL AT SOMERSET, VT. Elevation, 2 096 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.44	3.22	4.55	6.10	2.35	3.36	3.92	4.64	0.91	2.82	2.94	3.25	41.50
1915	8.01	5.95	0.45	3.09	1.89	2.79	12.19	7.33	3.49	2.92	2.32	7.10	57.53
1916	4.00	5.18	4.71	4.70	3.94	4.40	4.46	2.20	5.22	2.52	5.56	3.80	50.69
1917	4.70	3.54	4.70	2.05	4.89	4.57	4.01	6.83	1.21	8.26	0.91	3.63	49.30
1918	2.38	5.33	2.79	3.04	4.19	4.12	2.30	3.73	6.10	4.27	2.32	4.20	44.77
1919	3.52	3.16	6.11	2.22	6.36	1.87	4.37	4.23	6.24	5.77	5.05	2.24	51.14
1920	2.56	6.93	4.28	7.49	1.94	6.70	3.96	4.55	4.11	6.08	9.41	5.56	63.57
Av. 9 yrs.	4.28	4.52	4.50	4.05	4.16	3.52	4.76	4.47	3.97	5.09	4.28	4.38	51.98

RAINFALL AT ST. JOHNSBURY, VT. Elevation, 711 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.80	2.00	2.59	4.47	0.50	3.09	4.87	4.98	2.41	0.89	2.22	1.24	31.06
1915	1.98	3.47	0.30	1.98	2.01	2.79	6.38	4.67	3.22	1.48	1.79	3.03	33.10
1916	1.93	2.59	1.52	1.68	3.48	4.36	2.02	4.62	5.55	1.65	2.94	1.80	34.14
1917	2.84	1.21	2.13	2.29	1.82	6.13	3.10	7.86	1.61	5.63	1.04	1.77	37.43
1918	2.46	2.85	1.78	1.48	3.32	3.05	1.82	3.62	6.30	7.60	1.99	2.79	39.06
1919	1.93	1.71	2.74	2.53	3.01	2.82	0.96	3.92	2.59	4.88	3.10	1.28	31.47
1920	1.59	2.70	3.14	6.15	1.67	3.14	5.38	1.73	7.38	2.32	3.60	5.12	43.92
Av. 27 yrs.	2.18	2.20	2.70	2.43	2.94	3.30	4.06	4.14	3.72	2.78	2.51	2.50	35.46

RAINFALL AT VERNON, VT. Elevation, 310 feet.
(Connecticut River Power Co.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.67	0.90	2.77	5.43	1.73	2.33	0.79	4.24	0.21	1.69	1.83	2.03	26.62
1915	4.48	4.78	0.09	2.63	0.79	1.04	6.97	7.40	2.21	2.20	2.52	4.58	39.69
1916	1.46	3.29	1.74	2.44	2.86	4.30	4.07	3.55	6.84	1.40	3.45	1.83	37.23
1917	3.37	1.92	2.63	1.52	3.10	4.48	1.16	3.39	0.64	5.07	0.60	1.71	29.59
1918	1.83	2.94	1.61	2.87	2.76	3.29	0.90	3.13	6.70	1.15	2.34	3.46	32.98
1919	1.29	2.14	4.00	1.69	6.76	0.82	2.88	3.50	4.19	2.30	4.15	1.47	35.19
1920	1.35	2.15	2.09	6.34	2.03	3.93	2.51	4.78	6.55	1.09	2.82	3.96	39.60
Av. 23 yrs.	3.55	3.22	3.32	3.04	3.18	3.31	4.15	4.45	4.08	3.19	3.62	3.21	42.32

RAINFALL AT VICTORY, VT. Elevation, 800± feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	3.00	1.11	1.37	3.31	3.65	8.21	3.10	7.92	2.50	5.23	2.18	1.34	42.92
1918	1.57	3.14	2.44	1.86	4.97	4.97	3.80	3.90	8.11	9.47	2.09	2.63	48.95
1919	1.03	2.66	2.21	2.02	2.34	3.12	1.49	3.61	4.11	7.92	3.02	0.69	34.22
1920	1.62	1.86	2.15	4.83	0.84	2.13	6.64	3.85	7.30	1.52	2.29	4.19	39.22
Av. 4 yrs.	1.80	2.19	2.04	3.01	2.95	4.61	3.76	4.82	5.50	6.04	2.40	2.21	41.33

RAINFALL AT WELLS, VT. Elevation, 750 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.09	1.78	4.31	7.42	1.06	2.55	2.46	4.96	1.13	1.34	1.57	1.06	31.73
1915	3.38	5.48	0.37	2.00	1.98	2.30	6.69	2.80	2.82	3.37	2.06	4.45	37.70
1916	1.45	3.20	3.46	2.25	1.95	2.83	3.84	2.60	3.85	2.47	3.84	3.17	34.91
1917	2.47	1.49	2.22	1.83	2.05	4.04	2.70	4.36	1.06	6.15	1.28	1.98	31.63
1918	2.78	2.19	1.34	2.26	4.21	3.80	3.91	2.18	7.55	3.19	2.00	2.51	37.92
1919	2.37	1.35	3.77	2.02	...	...	...	...	...	...	...	1.24	....
1920	2.60	2.50	3.60	3.70	1.21	...	...	...	...	...	...	...	....
Av. 27 yrs.	2.57	2.72	3.09	2.42	3.32	3.32	3.96	4.00	3.83	3.12	2.61	2.71	37.67

RAINFALL AT WELLS RIVER, VT. Elevation, 750± feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	...	...	...	...	...	...	...	...	3.82	2.48	3.86	...	....
1917	...	...	2.28	2.58	3.18	...	...	...	2.18	4.12	...	...	....
1918	2.42	2.18	1.40	2.86	2.64	3.26	3.30	2.74	5.46	5.50	3.68	2.82	38.26
1919	2.86	2.59	3.50	3.00	3.46	3.90	3.41	3.18	4.26	3.77	3.98	1.54	39.45

(Gage changed to Woodsville, N. H., October 1, 1919.)

RAINFALL AT WHITE RIVER JCT., VT. Elevation, 400 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.16	1.82	4.30	4.82	1.17	1.26	2.16	3.93	0.44	0.68	2.23	1.85	26.82
1915	3.20	2.43	0.05	1.76	0.99	4.13	8.75	4.12	1.14	1.74	1.70	4.13	34.14
1916	1.52	3.42	3.26	3.48	3.22	4.06	3.59	1.93	5.29	0.99	2.67	1.52	34.95
1917	3.11	1.67	2.66	2.17	2.35	6.28	2.44	2.98	0.72	5.11	0.68	2.81	32.98
1918	2.79	2.25	1.95	2.51	3.00	3.68	1.35	3.56	5.92	2.43	1.80	2.33	33.57
1919	1.88	1.42	4.25	1.65	4.95	1.04	2.37	3.33	5.92	4.10	4.35	1.12	36.38
1920	1.41	2.86	2.32	5.97	2.62	2.99	3.90	2.14	2.68	3.47	4.66	4.64	39.66
Av. 7 yrs.	2.29	2.27	2.68	3.19	2.61	3.35	3.51	3.15	3.16	2.65	2.58	2.63	34.07

RAINFALL AT WILMINGTON, VT. Elevation, 1 500 feet.
(Mountain Mills.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	...	...	...	...	...	...	5.85	5.01	2.47	3.04	2.39	...	....
1916	...	...	...	...	...	...	4.02	2.50	3.65	2.71	4.52	3.65	....
1917	3.79	3.84	4.00	1.93	5.77	5.04	2.38	7.36	1.07	5.91	0.94	3.69	45.72
1918	4.35	4.43	3.49	3.24	3.41	4.75	1.61	2.93	7.20	2.71	2.37	4.07	44.56
1919	2.76	2.61	6.40	2.24	7.69	1.76	2.68	4.10	6.36	4.39	5.61	2.34	48.94
1920	2.23	6.03	3.82	1.06	2.34	6.06	3.08	2.94	4.34	4.67	7.83	7.00	51.40
Av. 4 yrs.	1.88	2.41	2.54	1.21	2.74	2.52	1.39	2.47	2.71	2.53	2.39	2.44	27.23

RAINFALL AT WOODSTOCK, VT. Elevation, 700 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.02	1.92	4.24	6.23	1.20	2.38	6.12	4.58	1.17	0.97	2.30	2.70	35.83
1915	2.66	4.17	0.09	1.95	0.69	2.48	11.11	7.49	2.38	2.61	2.52	3.55	41.70
1916	1.79	3.14	3.15	3.26	3.50	6.13	2.66	1.48	5.93	1.75	3.21	2.12	38.12
1917	3.05	1.09	1.79	1.66	4.19	5.69	1.83	2.26	0.98	5.49	0.89	2.26	31.18
1918	2.98	2.08	2.07	1.65	3.13	3.73	1.36	2.31	7.14	2.52	3.29	1.72	33.98
1919	1.57	1.40	4.83	1.67	5.46	2.31	2.13	3.67	4.99	3.91	4.56	1.46	37.96
1920	1.71	3.88	4.76	6.47	1.77	3.20	2.88	3.22	5.59	0.82	5.37	5.68	45.35
Av. 53 yrs.	3.00	2.79	3.08	2.67	3.44	3.29	3.95	3.38	3.40	3.08	3.06	2.96	38.10

MASSACHUSETTS.

RAINFALL AT ACUSHNET, MASS. Elevation, 50 feet.
(New Bedford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.81	2.90	4.45	5.05	3.19	0.90	4.72	2.52	0.90	2.90	3.21	4.82	39.37
1915	11.93	5.71	0.06	2.75	2.86	1.44	2.55	7.96	1.96	3.24	2.00	5.82	48.28
1916	2.05	5.65	5.64	4.80	5.28	4.50	11.79	1.96	1.93	3.28	3.18	3.14	53.20
1917	2.96	2.83	6.78	2.50	5.39	4.39	1.02	4.04	2.56	4.41	0.14	2.29	39.31
1918	3.56	2.68	1.74	4.36	1.70	3.42	2.48	1.73	4.09	0.94	2.67	4.84	34.21
1919	5.20	3.97	4.45	3.58	4.83	2.85	4.93	7.34	4.84	2.21	4.62	2.56	51.38
1920	3.31	3.51	3.45	4.62	5.29	7.65	2.06	2.98	1.32	1.57	4.49	2.33	42.58
Av. 43 yrs.	4.48	4.33	4.74	4.09	3.87	3.01	3.32	3.84	3.38	4.27	4.20	4.47	48.00

RAINFALL AT AGAWAM, MASS. Elevation, 410 feet.
(Provin Mt. Res., Springfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.19	4.09	4.99	4.90	3.65	2.35	3.08	2.68	0.31	2.41	3.88	3.39	38.92
1915	6.56	4.82	0.17	3.04	1.82	2.79	6.45	8.06	3.41	2.55	3.49	6.67	49.83
1916	1.52	6.12	3.04	3.26	3.83	4.40	5.06	2.62	4.36	1.33	3.62	3.42	42.58
1917	4.16	3.57	4.21	2.34	4.47	4.80	5.52	4.50	0.64	7.95	0.91	3.37	46.44
1918	2.29	3.28	2.10	2.64	2.32	3.69	1.81	4.11	6.21	1.12	2.15	3.57	35.29
1919	2.19	4.59	5.10	2.87	6.78	1.47	4.21	2.72	5.57	2.06	6.69	2.23	46.48
1920	2.43	3.46	4.36	6.12	3.09	7.85	2.97	5.42	8.78	0.82	6.53	6.78	58.61
Av. 7 yrs.	3.19	4.28	3.42	3.59	3.71	3.91	4.16	4.30	4.18	2.61	3.90	4.20	45.45

RAINFALL AT AMHERST, MASS. Elevation, 222 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	0.52	2.09	2.62	2.89	41.83
1915	6.52	7.02	0.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916	2.56	5.27	3.97	3.69	3.21	4.97	6.85	2.49	5.08	1.01	3.29	2.85	45.24
1917	3.30	1.98	4.08	1.83	4.13	5.27	3.36	7.06	2.42	6.60	0.63	2.56	43.22
1918	4.11	2.99	2.91	2.78	2.47	4.01	1.84	2.22	7.00	1.32	2.87	2.95	37.47
1919	2.02	2.80	4.22	2.37	6.20	1.09	4.17	4.80	4.45	1.81	6.20	1.48	41.61
1920	2.74	4.45	2.90	4.71	3.65	6.26	2.06	3.62	6.74	1.54	5.62	6.02	50.31
Av. 85 yrs.	3.38	3.27	3.60	3.18	3.80	3.61	4.40	4.36	3.66	3.71	3.62	3.58	44.17

RAINFALL AT ASHBY, MASS. Elevation, 1 000 feet.

(Watatic Pond, Fitchburg Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	5.42	3.51	0.06	2.36	1.90	1.44	10.81	7.62	1.44	3.02	3.61	4.51	45.70
1916	1.11	4.55	2.26	3.92	4.60	7.15	4.52	3.36	3.80	1.67	3.29	2.70	42.93
1917	2.32	2.14	3.85	1.89	4.33	6.43	3.23	5.16	1.08	6.79	1.93	2.04	41.49
1918	3.21	2.25	2.24	2.04	2.35	4.30	2.06	1.94	6.94	0.99	3.44	2.00	33.76
1919	3.74	3.44	5.62	2.28	6.82	1.39	3.10	2.55	6.94	2.95	7.54	1.77	48.14
1920	2.15	4.27	3.88	6.33	3.71	5.10	2.53	3.72	7.15	1.87	5.58	7.32	53.61
Av. 6 yrs.	2.99	3.41	2.99	3.14	3.95	4.30	4.37	4.06	4.56	2.88	4.23	3.39	44.27

RAINFALL AT ASHLAND, MASS. Elevation, 250 feet.

(Ashland Reservoir, Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.58	4.06	4.45	6.59	3.10	1.66	2.99	4.00	0.86	1.60	2.38	3.24	38.51
1915	6.63	3.44	0.06	2.42	1.94	3.66	7.51	5.40	1.29	2.74	2.65	4.67	42.41
1916	1.54	5.60	4.58	4.06	3.28	4.74	4.94	1.77	1.50	1.47	2.09	3.20	38.77
1917	3.49	2.64	4.76	2.62	4.70	4.05	1.06	5.74	1.61	5.51	1.26	2.66	40.10
1918	3.30	3.35	2.54	4.34	1.28	3.26	4.28	1.55	8.70	1.04	2.40	3.66	39.70
1919	3.34	3.12	4.22	2.72	3.79	1.39	4.66	3.68	5.06	2.13	5.11	1.85	41.07
1920	3.17	6.47	3.99	5.01	3.32	5.67	2.33	2.29	3.29	1.20	5.23	4.71	46.71
Av. 31 yrs.	3.86	4.15	4.32	3.66	3.36	3.07	3.46	3.54	3.58	3.53	3.41	3.77	43.71

RAINFALL AT ATHOL, MASS. Elevation, 1 000 feet.

(Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	1.94	1.64	5.08	4.22	4.38	1.30	1.81	2.00	3.01	1.94	2.38	4.31	34.01
1913	2.67	6.61	2.95	3.89	0.71	2.11	2.60	2.58	5.37	2.31	2.21	3.34	37.35
1914	3.26	2.10	3.85	4.71	2.76	2.26	2.12	4.71	0.44	1.80	2.52	1.96	32.49
1915	4.64	1.25	0.05	3.25	1.47	2.29	11.10	5.07	1.26	2.72	1.98	5.28	40.36
1916	1.35	4.26	3.14	2.51	3.14	4.66	7.15	3.53	7.23	1.27	2.61	1.99	42.84
1917	2.11	0.90	3.51	1.41	3.87	3.89	2.70	3.35	0.68	5.19	1.08	4.00	32.69
1918	0.53	1.75	0.42	3.09	2.47	5.05	2.44	2.58	7.32	1.12	2.45	2.23	31.45
1919	2.52	0.84	2.98	2.22	5.97	0.91	2.53	3.30	5.37	2.37	4.64	0.60	34.25
1920	2.09	3.35	0.26	3.30	3.46	4.97	1.59	6.27	2.66	0.93	2.66	6.27	37.81
Av. 9 yrs.	2.35	2.52	2.47	3.18	3.14	3.05	3.78	3.71	3.71	2.18	2.50	3.33	35.92

RAINFALL AT ATTLEBORO, MASS. Elevation, 100 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1910	4.85	3.86	1.63	2.79	3.25	3.90	2.43	3.63	1.95	1.70	5.24	2.17	37.40
1914	4.55	3.29	3.59	4.81	2.43	0.30	3.46	2.47	0.68	2.75	3.17	3.05	34.55
1915	7.02	2.46	0.07	1.22	1.89	2.16	9.34	5.67	0.83	1.66	2.61	5.23	40.16
1916	1.41	4.71	1.40	3.28	5.28	4.83	7.63	2.19	1.19	2.41	1.69	2.26	38.28
1917	3.22	1.37	4.89	2.35	4.64	4.87	0.87	5.68	2.09	6.29	0.62	2.04	38.93
1918	3.55	2.96	1.94	5.33	0.93	3.39	3.76	2.27	9.38	0.31	2.06	3.66	39.54
1919	4.18	3.33	4.88	3.07	4.40	1.44	4.40	5.31	5.48	1.58	4.22	2.27	44.56
1920	2.63	4.89	4.31	5.13	4.31	5.72	2.00	2.73	1.61	1.21	4.67	4.01	43.22
Av. 20 yrs.	3.88	4.11	4.02	3.85	3.43	3.29	4.03	3.44	4.42	2.79	3.35	3.56	44.17

RAINFALL AT BARNSTABLE, MASS. Elevation, 20 feet.
(Hyannis.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.46	4.04	4.51	4.11	4.79	1.52	4.85	3.70	1.00	2.35	2.43	5.46	41.22
1915	9.15	4.34	**0.09**	**2.92**	**2.50**	**2.72**	**0.77**	**4.69**	**1.36**	**4.60**	**2.44**	**4.06**	39.64
1916	**1.38**	**4.21**	**4.58**	**4.09**	**4.71**	8.10	5.20	0.66	3.63	1.82	1.32	4.37	44.07
1917	2.73	3.33	5.98	4.47	4.20	6.65	2.84	2.46	3.10	4.56	0.57	2.55	43.44
1918	3.38	2.41	2.99	3.54	1.10	3.80	2.08	1.91	1.93	1.24	1.67	3.95	30.00
1919	5.79	3.29	4.35	2.82	3.66	2.58	7.44	7.83	6.79	3.23	4.28	3.10	55.16
1920	2.67	7.87	6.05	4.88	4.58	5.45	1.93	2.67	2.27	3.22	4.10	3.88	49.57
Av. 29 yrs.	4.11	3.73	4.48	3.66	3.56	3.10	2.93	3.47	2.87	3.52	3.79	4.10	43.32

RAINFALL AT BEDFORD, MASS. Elevation, 170 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.04	2.45	3.55	4.17	2.28	1.85	2.38	4.78	0.11	1.60	2.03	2.85	31.09
1915	4.45	3.62	T	1.59	1.56	1.51	10.69	5.36	1.24	2.87	2.65	4.60	40.14
1916	1.47	5.15	2.70	4.17	3.24	5.11	2.55	2.42	2.13	0.93	2.25	2.47	34.59
1917	2.41	2.24	3.29	2.51	4.07	4.46	1.41	4.24	1.74	4.89	0.85	2.46	34.57
1918	2.34	2.45	2.52	2.47	2.31	3.03	3.39	2.48	7.74	1.16	2.38	2.82	35.09
1919	3.57	3.27	3.94	2.64	5.45	1.08	3.45	3.85	5.26	2.37	6.21	1.65	42.74
1920	2.48	6.50	3.82	5.06	3.17	5.34	1.57	1.91	3.83	1.10	4.14	5.40	44.32
Av. 28 yrs.	3.09	3.36	3.47	3.28	3.19	2.98	3.28	3.51	3.47	3.01	3.07	3.25	38.96

RAINFALL AT BILLERICA (NORTH), MASS. Elevation, 100 feet.
(Talbot Chemical Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1889	5.10	1.56	1.62	3.81	5.10	4.92	7.18	4.14	3.17	3.38	6.78	2.30	49.06
1890	2.44	3.80	7.96	2.36	5.95	3.14	1.86	5.66	3.57	7.75	0.80	2.85	48.14
1891	4.80	3.15	5.40	2.60	2.53	2.42	4.00	1.90	2.10	2.32	3.60	3.27	38.09
1892	4.00	2.55	3.20	0.50	5.16	5.47	1.00	5.74	3.03	2.35	6.19	1.34	40.53
1893	2.53	7.15	2.29	2.46	7.01	3.16	2.24	5.88	3.17	3.50	1.77	4.00	45.16
1894	2.89	3.05	0.92	2.45	4.42	1.22	5.65	1.45	2.70	5.24	2.41	3.60	36.00
1895	2.90	1.00	2.34	3.48	1.62	3.47	1.53	2.83	1.99	7.74	8.99	2.35	40.24
1896	2.13	4.76	4.94	1.25	1.80	2.05	2.95	2.58	7.75	3.20	3.68	2.30	39.39
1897	3.60	2.65	4.05	2.85	3.45	6.10	3.75	5.60	3.30	0.40	6.20	4.35	46.30
1898	5.10	5.16	1.25	5.20	2.73	4.56	2.47	7.81	2.00	6.13	6.30	3.30	52.01
1899	2.95	3.85	7.00	3.05	2.00	2.92	2.80	1.98	4.30	1.35	4.07	0.82	37.09
1900	4.40	9.18	6.05	1.25	3.70	2.40	2.38	2.54	3.55	2.65	5.92	2.62	46.64
1901	1.20	1.15	4.65	7.20	6.95	1.05	5.90	3.00	2.30	4.60	2.45	6.65	47.10
1902	2.35	6.20	4.50	5.20	1.13	1.55	3.35	3.85	2.00	6.62	0.90	6.00	43.65
1903	2.70	3.30	6.05	3.10	0.50	9.35	2.25	2.75	1.35	4.10	1.68	2.70	39.83
1904	2.60	2.85	2.72	10.69	2.60	3.38	5.57	3.02	5.09	1.54	1.40	2.00	43.46
1905	6.78	1.15	1.60	2.55	0.93	5.16	1.42	3.88	7.20	1.77	0.75	3.70	36.89
1906	2.25	0.60	2.45	3.40	5.97	**4.71**	**5.43**	**2.56**	**1.44**	**2.24**	3.70	3.40	38.15
1907	3.47	1.75	2.40	4.60	3.15	2.95	5.39	0.95	7.50	4.35	5.80	4.85	47.16
1908	3.45	3.07	**2.53**	0.50	4.65	**0.80**	**4.68**	**4.38**	**0.43**	**2.55**	0.00	3.64	30.68
Av. 20 yrs.	3.38	3.40	3.70	3.42	3.57	3.54	3.59	3.62	3.40	3.69	3.67	3.30	42.28

RAINFALL AT BOSTON, MASS. Elevation, 185 feet.
(West Roxbury.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	3.03	2.38	4.71	3.52	3.90	0.26	4.81	2.94	1.55	1.48	2.94	5.02	36.54
1913	2.88	2.66	5.00	4.70	2.95	1.68	2.82	6.41	2.72	6.96	2.45	3.29	44.52
1914	3.71	3.31	3.74	5.74	2.93	1.40	2.69	3.54	0.27	1.64	2.65	3.73	35.35
1915	6.79	3.17	T	2.93	1.39	1.74	10.39	5.89	0.79	2.80	2.90	5.57	44.36
1916	1.39	5.02	3.48	4.30	3.38	4.94	4.82	2.69	1.39	1.11	1.94	3.40	37.86
1917	3.03	2.43	4.39	2.50	5.22	4.21	0.73	10.65	2.18	5.96	0.64	2.88	44.82
1918	3.19	2.43	3.32	4.66	1.45	2.42	3.83	1.19	9.50	0.96	1.91	3.46	38.32
1919	3.43	2.97	4.86	2.79	4.35	1.18	4.48	6.02	6.48	2.51	4.84	1.54	45.45
1920	3.02	6.65	3.83	5.75	4.86	6.29	2.88	3.76	3.00	1.75	5.67	4.00	51.46
Av. 9 yrs.	3.38	3.45	3.71	4.10	3.38	2.68	4.16	4.79	3.10	2.80	2.88	3.65	42.08

RAINFALL AT BOSTON, MASS. Elevation, 90 feet.

(Brookline Pumping Station, West Roxbury.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	...	...	...	...	...	...	...	...	...	7.43	1.36	3.29	....
1914	3.71	3.27	3.94	5.56	2.80	1.37	2.85	3.60	0.23	1.66	2.83	3.63	35.45
1915	7.03	3.32	T	3.26	1.84	1.70	9.65	5.55	0.79	2.74	2.27	5.05	43.20
1916	1.34	4.92	3.69	4.57	3.17	5.62	4.72	2.92	1.52	1.20	1.86	2.68	38.21
1917	3.13	2.00	4.00	2.64	5.14	4.16	0.80	10.94	2.20	5.71	0.83	1.53	43.08
1918	2.76	3.21	1.62	4.80	1.34	2.49	3.51	1.40	9.20	1.02	1.77	3.29	36.41
1919	3.47	3.12	4.49	2.69	4.64	1.27	5.36	5.10	6.81	2.61	5.14	1.69	46.39
1920	3.43	7.38	3.41	5.48	4.64	6.32	2.69	4.27	3.45	1.16	5.74	3.95	51.92
Av. 7 yrs.	3.55	3.89	3.02	4.14	3.37	3.28	4.23	4.83	3.46	2.30	2.92	3.11	42.10

RAINFALL AT BOSTON, MASS. Elevation, 60 feet.

(Blue Hill Observatory, Valley Station, Readville.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1888	...	...	...	...	...	...	...	6.26	8.82	4.75	9.70	5.50	....
1889	6.81	1.92	2.36	3.92	4.47	5.17	8.47	3.79	4.61	4.98	5.64	2.25	54.39
1890	2.53	2.40	7.64	3.10	5.58	1.90	1.55	2.82	6.80	8.06	1.11	5.24	48.73
1891	6.91	4.97	4.85	2.91	2.12	3.84	3.36	4.70	3.14	6.06	2.56	4.04	49.46
1892	5.06	2.46	3.47	0.82	5.16	3.26	3.51	5.15	2.06	2.23	5.50	1.24	39.92
1893	2.62	6.32	4.17	2.84	4.30	2.20	2.62	6.75	1.67	4.32	2.16	5.01	44.98
1894	3.37	3.78	1.02	2.84	3.14	0.77	2.67	1.34	2.64	6.27	4.32	4.41	36.57
1895	4.13	0.83	3.00	4.99	2.31	1.30	3.21	3.34	2.76	7.61	8.48	2.66	44.62
1896	2.48	4.44	6.09	1.29	2.87	3.51	2.78	2.60	9.03	4.06	3.96	1.78	44.89
1897	3.50	2.31	2.78	3.31	4.74	3.49	4.32	5.31	2.34	0.64	7.00	4.07	43.81
1898	3.90	7.00	2.37	5.84	3.88	2.47	6.20	6.05	2.44	7.86	7.03	1.97	57.01
1899	5.17	4.53	5.67	1.62	1.05	2.23	4.52	1.33	6.34	2.53	2.42	1.91	39.32
1900	4.39	7.37	4.94	2.20	5.30	2.51	2.83	1.68	4.42	4.10	5.48	2.67	47.89
1901	2.10	0.79	7.43	7.27	5.92	1.52	6.33	3.00	3.72	3.75	3.39	8.12	53.34
1902	1.91	5.04	6.08	3.07	1.82	3.22	2.85	2.26	3.01	4.73	1.44	6.65	42.08
1903	4.36	4.14	7.45	3.96	0.81	6.61	3.56	4.57	1.83	5.08	1.42	3.23	47.02
1904	5.90	2.91	3.10	9.35	2.50	3.19	2.23	1.99	6.03	2.64	2.39	2.64	44.87
1905	3.56	1.99	2.72	3.08	1.65	4.68	1.97	3.09	5.21	1.41	2.10	3.82	35.28
1906	3.00	3.17	6.17	2.36	5.32	1.81	6.06	1.54	3.66	4.69	2.93	3.54	44.25
1907	3.33	2.30	1.92	4.01	3.31	3.32	1.02	1.35	7.84	3.04	6.67	5.33	43.44
1908	3.52	4.19	3.52	1.63	3.90	1.22	4.05	3.91	1.00	4.26	1.15	2.78	35.13
1909	4.29	5.53	4.20	4.37	2.46	3.07	0.86	4.60	4.37	1.30	4.36	3.82	43.23
1910	6.32	4.43	1.82	2.50	1.37	3.80	1.75	1.73	2.06	1.54	5.70	2.61	35.63
1911	3.04	3.12	3.31	2.87	0.86	4.64	4.51	6.66	3.39	2.95	5.68	3.23	44.26
1912	3.78	2.25	5.16	3.87	3.91	0.48	4.17	3.79	1.61	1.54	3.23	5.68	39.47
1913	2.88	3.52	5.25	4.46	2.88	3.02	2.40	2.13	2.56	6.77	2.45	3.47	41.79
1914	4.09	3.57	4.79	5.37	2.83	1.34	3.32	3.99	0.30	1.78	2.91	4.20	38.49
1915	7.15	4.14	0.05	2.06	1.58	1.45	10.26	4.80	0.63	2.75	2.23	5.51	42.61
1916	1.55	6.20	4.47	4.92	3.64	5.11	6.82	2.56	1.60	1.55	1.69	3.56	43.67
1917	3.15	3.04	4.76	3.04	5.54	4.70	1.16	9.35	2.91	6.35	0.58	3.12	47.70
1918	3.34	2.89	3.34	4.11	3.03	2.41	5.40	1.55	9.71	1.16	2.11	4.32	43.37
1919	4.09	3.50	5.11	3.30	5.50	2.40	5.65	6.88	7.03	3.06	5.61	2.44	54.57
1920	3.65	7.11	5.10	6.31	7.32	7.30	2.85	4.98	2.79	2.14	6.36	4.62	60.53
Av. 32 yrs.	3.93	3.81	4.19	3.67	3.47	3.06	3.85	3.77	3.73	3.78	3.75	3.75	44.76

RAINFALL AT BOSTON, MASS. Elevation, 124 feet.

(U. S. Weather Bureau.)*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1871	0.92	2.63	4.55	3.79	4.34	5.55	3.22	3.08	1.30	5.88	6.42	3.38	45.06
1872	2.11	2.31	4.05	1.31	3.29	4.84	4.00	10.68	6.04	4.85	3.66	3.09	50.23
1873	5.76	3.21	3.76	3.83	5.16	0.54	3.84	6.21	2.91	5.33	8.34	5.64	54.53
1874	4.32	3.41	1.60	7.97	3.71	3.94	3.47	6.67	2.05	1.39	2.85	2.14	43.52
1875	3.68	3.74	5.04	4.92	3.76	7.25	3.93	3.50	3.12	4.99	5.47	0.75	50.15
1876	1.87	4.54	7.19	3.61	2.70	1.72	5.86	1.23	3.84	1.66	11.03	3.71	48.96
1877	3.33	0.45	9.79	4.19	3.38	3.21	2.27	4.49	0.60	8.84	9.62	1.32	51.49
1878	7.60	4.40	5.91	6.14	1.03	2.28	4.58	7.66	3.47	6.76	8.94	6.76	65.53
1879	2.79	4.35	3.90	6.58	0.97	6.24	3.09	6.71	1.84	0.91	2.97	4.22	44.57
1880	3.72	4.11	3.25	2.85	1.63	0.75	6.86	2.90	2.36	3.15	2.30	3.42	37.30
1881	7.21	4.89	9.86	1.66	4.16	7.79	2.96	1.23	2.50	2.84	3.73	3.80	52.63
1882	3.68	4.77	3.35	2.50	6.05	1.03	3.91	1.46	10.93	2.29	1.20	2.65	43.82
1883	3.59	2.74	2.33	2.83	5.11	2.07	2.73	0.39	1.50	6.40	2.08	3.71	35.48
1884	6.27	5.74	4.86	4.76	3.31	4.01	4.25	5.01	0.31	3.17	3.03	4.46	49.18
1885	5.33	3.00	1.15	3.30	4.26	3.70	1.44	7.64	1.70	5.71	5.78	2.09	45.10
1886	7.08	7.04	3.20	1.70	3.08	1.34	1.81	3.64	2.73	3.27	3.59	3.66	42.14
1887	4.86	3.69	3.86	2.62	1.67	1.98	3.59	3.05	0.97	2.53	2.22	2.71	33.75
1888	2.26	2.36	3.32	2.04	5.20	2.69	1.79	6.53	6.77	3.58	4.97	4.38	45.89
1889	4.11	1.54	1.19	3.07	4.15	2.77	5.80	3.95	3.19	3.31	4.91	1.83	39.82
1890	2.00	2.29	5.88	2.29	4.48	2.21	1.93	2.70	5.04	5.63	0.97	3.72	39.14
1891	4.39	3.66	3.94	1.71	1.56	3.06	3.73	3.87	2.29	5.56	2.35	3.58	39.70
1892	4.62	2.15	3.91	0.93	5.15	3.05	2.56	4.87	1.90	2.31	4.45	1.12	37.02
1893	2.56	6.22	2.80	3.13	5.23	2.20	1.72	6.46	1.59	2.94	1.83	5.16	41.84
1894	3.01	3.15	1.01	3.78	4.12	0.80	3.09	3.03	2.14	5.11	3.10	4.28	36.62
1895	3.79	1.11	2.72	3.65	2.71	1.73	2.98	3.24	1.53	6.19	8.07	2.45	40.17
1896	2.25	3.94	5.41	1.56	1.68	2.71	2.90	2.15	6.40	3.15	3.70	1.70	37.55
1897	3.16	2.12	2.79	3.17	4.00	4.46	4.22	3.95	2.38	0.41	6.19	3.92	40.77
1898	3.50	4.81	1.82	6.39	4.33	1.60	4.42	6.38	1.93	7.17	5.32	2.19	49.86
1899	4.19	3.03	5.95	1.29	0.81	2.86	2.52	2.52	5.09	2.40	2.51	1.52	34.69
1900	4.20	6.83	4.60	1.90	5.07	1.85	2.69	2.46	4.62	3.41	4.17	2.25	44.05
1901	1.56	0.66	6.58	7.43	6.31	1.31	5.20	3.25	2.50	3.02	2.41	8.49	48.72
1902	1.65	4.19	5.29	2.87	1.07	1.77	2.88	2.20	2.08	4.36	1.09	4.48	33.93
1903	3.43	3.90	5.95	4.43	0.32	7.19	2.99	3.33	2.43	3.95	1.48	2.57	41.97
1904	4.80	2.49	2.43	9.14	3.38	2.06	1.23	2.19	5.57	2.13	1.70	2.52	39.64
1905	4.09	1.59	2.25	2.14	1.47	5.23	1.00	3.39	5.10	0.82	1.77	3.23	32.08
1906	2.96	2.66	5.45	2.15	4.91	2.57	5.38	1.58	2.64	3.88	2.55	3.96	40.69
1907	2.54	1.88	1.66	3.31	3.12	2.56	1.09	1.10	7.43	2.54	6.02	4.31	37.56
1908	2.47	2.96	2.97	1.70	3.78	1.08	3.17	4.35	0.68	3.70	0.74	2.47	30.07
1909	3.94	4.71	3.28	3.92	2.33	4.45	0.97	3.55	5.15	1.07	4.11	3.19	40.67
1910	4.25	3.44	1.25	2.22	1.02	4.89	1.15	0.98	2.14	1.14	3.75	2.10	28.33
1911	2.28	2.85	2.95	2.28	0.35	3.67	4.65	4.17	2.95	2.27	4.29	3.07	35.78
1912	2.87	2.38	4.18	3.07	4.04	0.27	5.16	1.94	1.67	1.00	2.61	5.36	34.55
1913	2.38	2.99	4.81	4.77	3.22	0.64	2.69	2.86	2.51	6.04	2.15	3.05	38.11
1914	3.26	3.07	4.16	5.87	2.78	1.40	2.64	3.20	0.21	1.54	2.72	3.46	34.31
1915	6.33	3.47	T	1.86	1.64	1.39	8.85	5.63	0.69	2.82	2.14	3.94	38.76
1916	1.23	5.18	3.20	4.51	2.83	5.04	5.67	2.19	1.90	0.94	1.67	3.00	37.36
1917	2.82	2.67	3.73	2.72	4.45	4.05	1.10	7.06	1.91	5.33	0.59	2.56	38.99
1918	3.11	2.30	3.19	3.08	1.99	1.94	2.64	1.56	9.19	0.99	1.20	3.21	34.40
1919	3.62	2.66	4.11	2.33	4.25	1.08	4.63	5.07	5.83	2.13	5.36	1.63	42.70
1920	2.72	5.88	3.72	5.68	5.26	5.78	1.56	2.32	1.90	1.64	5.46	3.89	45.81
Av. 50 yrs.	3.61	3.40	3.88	3.50	3.29	2.97	3.34	3.79	3.15	3.45	3.79	3.32	41.49

* The reliability of these observations was questioned during a period of several years following the year 1886 on account of the elevation of the gage.

RAINFALL AT BOYLSTON, MASS. Elevation, 530 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1896	2.12	7.30	4.44	1.89	2.45	2.53	4.83	2.23	7.60	3.95	2.98	2.31	*44.63
1897	3.39	2.86	4.21	2.63	4.60	4.85	7.06	3.94	2.21	0.92	7.45	6.22	*50.34
1898	7.38	4.04	2.34	4.81	3.37	2.93	3.57	10.72	3.22	6.76	7.50	3.75	*60.39
1899	3.27	5.18	6.83	2.08	1.64	5.49	3.33	3.18	4.63	2.65	2.12	2.10	*42.50
1900	5.02	8.81	6.73	3.02	3.82	3.25	3.80	3.29	3.85	1.87	6.44	3.34	*53.24
1901	1.93	1.20	6.18	9.25	7.05	1.13	6.03	4.62	3.34	3.72	2.84	9.80	57.09
1902	2.50	5.70	5.78	4.61	1.79	2.01	3.41	3.67	4.84	5.72	1.11	7.19	48.33
1903	3.27	4.67	6.58	3.29	0.99	11.83	3.43	4.00	2.66	4.72	2.17	4.13	51.74
1904	4.80	2.72	3.21	8.35	2.58	2.94	3.63	3.67	4.57	1.56	1.73	3.06	42.82
1905	5.98	1.78	3.64	2.83	0.66	5.18	6.07	3.09	7.84	1.90	2.51	3.77	45.25
1906	2.54	3.03	5.56	3.04	6.57	6.24	6.40	2.79	2.64	3.19	2.66	4.18	48.84
1907	3.06	2.27	2.05	3.26	3.11	3.64	2.48	1.61	10.10	5.10	5.99	4.76	47.43
1908	3.48	4.62	3.12	2.27	5.48	1.08	4.01	6.93	1.20	2.37	1.07	3.02	38.65
1909	3.45	6.22	4.65	5.68	2.90	3.10	4.07	3.42	4.72	1.20	2.02	3.64	45.07
1910	5.72	5.12	0.92	2.76	1.67	4.52	1.53	4.13	3.14	1.49	4.10	2.43	37.53
1911	2.93	2.75	3.92	2.56	1.44	2.77	3.14	5.21	3.03	4.46	4.17	3.09	39.47
1912	2.90	2.72	5.94	4.26	5.81	0.33	2.84	2.92	1.81	2.52	4.11	4.79	40.95
1913	3.27	2.66	5.18	4.07	3.86	1.05	2.20	2.27	3.92	6.05	2.48	3.13	40.14
1914	3.85	3.36	4.67	4.82	3.26	1.86	3.28	4.14	0.13	2.19	2.78	3.85	38.19
1915	6.31	3.58	0.04	1.47	1.59	3.69	9.18	7.00	1.10	3.12	2.81	4.48	44.37
1916	1.54	6.04	3.83	3.96	3.49	6.58	5.50	1.73	4.63	1.42	2.88	2.76	44.36
1917	3.37	2.73	4.81	1.80	4.17	4.23	1.47	5.96	1.28	5.27	1.56	2.58	39.23
1918	3.52	3.97	2.26	3.82	1.07	5.25	4.12	2.45	8.80	1.55	2.80	3.47	43.08
1919	2.94	3.36	5.13	2.65	5.23	2.17	4.69	3.89	6.23	2.19	6.06	2.14	46.68
1920	3.07	6.04	4.16	5.59	4.86	6.40	2.85	1.93	6.17	0.53	5.83	6.00	53.43
Av. 25 yrs.	3.74	4.10	4.25	3.79	3.34	3.80	4.12	3.95	4.15	3.06	3.45	4.00	45.75

* South Clinton gage.

From 1896–1900, inclusive, the Metropolitan Water Works maintained a gage at South Clinton in the area subsequently covered by Wachusett Reservoir. After 1900 the gage was removed to Boylston, near the southern shore of the reservoir.

RAINFALL AT BRIDGEWATER, MASS. Elevation, 60 feet.

(State Farm.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	...	...	0.96	4.40	2.72	2.20	2.29	3.67	5.33	....
1915	9.22	3.28	0.03	1.85	2.47	2.95	2.74	5.33	1.97	3.01	2.50	5.24	40.59
1916	1.78	4.37	3.20	4.77	4.79	5.03	10.10	1.57	2.81	2.80	2.76	3.20	47.18
1917	3.61	2.03	5.34	3.76	5.70	5.22	1.64	6.82	3.23	6.53	0.41	3.68	47.97
1918	3.40	3.50	2.58	5.76	0.92	3.04	4.62	1.66	7.08	0.65	2.06	3.66	38.93
1919	4.27	3.65	3.98	3.62	5.02	1.45	6.00	6.96	7.64	2.39	4.30	2.30	51.58
1920	2.71	4.89	4.37	5.18	4.95	6.82	3.45	3.53	3.51	1.80	4.46	3.31	48.98
Av. 6 yrs.	4.17	3.62	3.25	4.16	3.98	4.08	4.76	4.31	4.37	2.86	2.75	3.56	45.87

RAINFALL AT BROCKTON, MASS. Elevation, 200 feet.

(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.03	3.26	3.31	4.04	2.48	0.86	3.89	3.65	0.78	1.98	2.71	3.47	33.46
1915	6.49	3.45	T	1.41	2.87	2.51	4.50	4.14	0.74	2.40	2.30	4.67	35.48
1916	1.75	5.25	3.59	3.20	3.77	4.88	6.26	2.66	2.16	2.38	1.76	3.58	41.24
1917	3.00	1.80	3.75	2.34	4.21	4.91	1.28	7.25	2.77	5.96	0.46	2.18	39.91
1918	3.18	2.41	2.45	4.04	2.54	2.46	3.76	1.34	10.27	0.96	2.18	3.51	39.10
1919	3.65	3.44	4.01	3.00	4.33	0.95	5.17	5.70	6.94	2.67	5.29	2.24	47.39
1920	3.11	4.65	4.63	4.81	4.39	6.13	3.49	3.04	2.00	2.85	3.61	3.52	46.23
Av. 27 yrs.	3.29	3.14	3.62	3.46	3.13	2.94	3.49	3.16	3.85	3.32	3.34	3.38	40.12

RAINFALL AT CAMBRIDGE, MASS. Elevation, 75 feet.

(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.53	3.79	4.34	6.10	2.63	1.93	2.64	3.35	0.25	0.24	2.72	3.55	35.07
1915	6.33	3.73	T	3.08	2.32	1.57	10.11	6.91	0.74	2.71	2.19	5.09	44.78
1916	1.43	5.42	3.74	4.74	3.13	5.17	4.47	2.51	1.81	1.08	1.79	3.36	38.68
1917	3.14	2.75	4.21	3.01	4.55	4.06	1.14	7.91	1.79	6.41	0.81	2.50	42.28
1918	2.84	2.52	3.54	3.37	2.09	2.28	3.46	1.86	10.23	1.54	1.86	3.65	39.24
1919	3.95	3.27	4.41	2.73	4.45	1.06	4.34	4.76	5.91	2.20	5.68	1.61	44.37
1920	2.82	6.52	3.60	5.47	4.31	6.29	1.45	1.28	2.67	1.58	6.58	4.88	47.45
Av. 21 yrs.	3.49	3.90	3.94	3.98	3.14	3.03	3.37	3.34	3.69	2.67	3.09	3.84	41.48

RAINFALL AT CAMBRIDGE, MASS. Elevation, 40 feet.

(Fresh Pond.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1878	...	...	...	...	...	...	...	...	...	...	...	4.67	....
1879	2.25	2.92	4.26	5.13	1.22	4.58	2.76	5.93	1.50	0.67	2.99	3.76	37.97
1880	2.62	3.49	2.85	1.94	1.44	0.73	6.49	3.48	1.63	2.63	2.25	1.98	31.53
1881	5.03	4.14	6.07	1.83	3.32	6.27	3.41	1.13	2.74	2.85	4.08	3.30	44.17
1882	4.73	4.48	2.49	2.27	4.93	2.73	2.08	1.41	7.80	2.18	1.21	1.87	38.18
1883	2.94	2.85	1.76	2.48	4.10	2.28	2.38	0.34	1.18	5.61	1.96	2.94	30.82
1884	4.81	6.67	4.91	4.22	3.18	3.79	4.56	4.76	0.70	2.90	2.63	4.60	47.73
1885	5.43	2.94	1.06	3.61	3.77	4.10	1.72	5.21	1.78	5.56	9.20	1.82	46.20
1914	3.52	2.60	4.26	5.46	2.63	1.41	2.53	2.57	0.51	1.31	2.54	3.02	32.36
1915	6.43	2.70	0.00	2.79	1.57	5.03	6.50	6.85	1.05	2.04	1.83	3.03	39.82
1916	1.06	4.67	3.28	4.18	2.81	6.19	3.23	2.18	1.14	1.04	1.63	2.62	34.03
1917	2.89	4.06	5.48	3.31	4.38	3.40	0.46	4.76	1.61	5.48	0.90	2.08	38.81
1918	2.61	5.51	3.64	3.98	0.79	2.94	3.95	1.71	8.36	0.47	1.90	3.20	39.06
1919	3.52	2.97	3.02	2.70	4.27	0.67	5.19	4.16	6.06	1.94	5.06	1.61	41.17
1920	2.46	7.50	3.58	4.91	4.02	5.90	1.49	1.01	2.70	1.02	5.38	3.68	43.65
Av. 42 yrs.	3.63	3.78	3.67	3.40	3.35	3.14	3.36	3.46	3.32	3.32	3.43	3.33	41.19

RAINFALL AT CAMBRIDGE, MASS. Elevation, 75 feet.

(Harvard College Observatory.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.36	4.31	3.82	5.99	2.74	1.64	2.59	2.85	0.27	1.58	2.73	3.51	33.39
1915	6.50	3.84	0.00	3.21	3.02	1.49	10.34	7.72	1.05	2.21	2.27	5.03	46.68
1916	1.42	5.59	3.10	5.05	3.11	5.20	2.36	2.24	1.20	1.50	0.90	4.00	35.67
1917	3.05	2.45	3.88	2.89	4.81	3.60	0.63	6.22	1.60	6.21	0.64	3.15	39.13
1918	3.32	2.55	3.62	3.20	2.04	2.56	3.59	1.79	9.67	1.14	1.86	3.41	38.75
1919	3.80	3.63	4.47	2.86	4.60	0.97	3.72	3.49	6.72	2.02	5.23	2.15	43.66
1920	3.43	9.44	4.40	5.56	4.33	6.36	1.28	0.53	2.27	2.25	6.08	3.96	49.89
Av. 80 yrs.	3.90	3.64	3.92	3.66	3.42	3.13	3.35	4.17	3.52	3.45	3.89	3.56	43.61

RAINFALL AT CHESTER, MASS. Elevation, 600 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.69	2.43	6.32	3.65	4.35	0.23	2.24	2.00	3.24	4.61	5.33	2.25	40.34
1914	2.73	2.06	3.81	5.08	3.46	1.66	3.32	2.99	0.40	1.08	2.99	2.65	32.23
1915	5.26	4.44	0.21	2.41	2.02	2.67	8.49	8.68	2.76	3.19	2.71	4.00	46.84
1916	2.00	4.84	3.15	3.11	2.96	4.15	4.23	2.75	4.97	1.32	3.30	3.89	40.67
1917	3.54	2.77	3.59	1.23	3.48	5.50	1.09	0.50	0.63	7.46	1.03	4.85	35.67
1918	3.84	2.84	2.33	3.12	4.02	3.72	2.55	2.70	6.01	1.82	2.49	3.38	38.82
1919	2.59	2.70	4.36	3.16	6.77	2.10	5.15	4.33	4.91	2.40	6.08	2.50	47.05
1920	1.90	4.75	2.40	5.79	1.55	6.98	1.83	6.01	5.58	1.60	5.37	4.63	48.39
Av. 8 yrs.	3.19	3.35	3.27	3.44	3.58	3.38	3.61	3.75	3.56	2.94	3.66	3.52	41.25

RAINFALL AT CHESTNUT HILL RESERVOIR. Elevation, 124 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.96	4.34	4.42	6.19	2.77	1.73	2.77	3.83	0.35	1.71	2.94	3.98	38.99
1915	6.89	3.44	T	2.92	1.48	5.42	6.75	6.39	1.02	2.90	2.38	5.33	44.92
1916	1.87	5.65	4.18	4.74	3.56	6.03	5.19	2.78	1.45	1.27	1.88	3.31	41.91
1917	3.69	2.68	4.81	3.01	5.32	3.82	1.00	7.50	1.98	6.38	1.08	2.35	43.62
1918	3.46	4.04	1.98	4.50	1.17	2.40	3.93	1.68	9.34	1.25	1.88	4.18	39.81
1919	3.16	3.89	5.04	3.09	4.99	1.51	5.08	4.75	6.96	2.55	5.13	2.00	48.15
1920	3.67	7.16	4.16	6.10	4.80	6.26	1.76	1.75	3.12	1.23	6.09	4.48	50.56
Av. 48 yrs.	4.11	4.17	4.14	3.84	3.44	3.18	3.57	3.97	3.50	3.70	3.99	3.64	45.25

RAINFALL AT CLINTON, MASS. Elevation, 370 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.17	4.86	5.61	5.29	3.73	2.00	4.02	3.78	0.25	1.65	3.20	3.74	42.30
1915	6.27	3.61	0.06	1.70	1.51	2.92	8.38	5.83	1.01	3.42	2.73	5.12	42.56
1916	1.54	6.37	4.36	3.87	3.30	6.53	5.41	2.14	4.05	1.28	2.86	2.99	44.70
1917	3.40	2.54	4.93	1.64	3.87	4.79	1.28	6.46	1.12	5.74	1.77	2.70	40.24
1918	3.52	3.79	2.63	4.11	1.19	4.00	3.24	2.11	8.35	1.26	2.59	3.21	40.00
1919	2.97	3.63	5.19	2.42	5.78	1.81	6.13	4.08	5.73	2.50	6.79	2.36	49.29
1920	3.39	6.42	5.04	6.10	4.50	6.79	3.81	2.47	6.35	0.52	5.80	6.54	57.73
Av. 19 yrs.	3.66	3.93	4.18	3.81	3.36	4.01	3.82	3.90	4.09	3.07	3.17	3.98	44.98

RAINFALL AT COLRAIN, MASS. Elevation, 500 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.78	2.45	5.80	2.82	3.93	0.75	1.42	1.81	4.20	5.78	3.76	3.46	39.96
1914	3.10	2.67	4.76	5.68	2.39	1.80	2.86	4.64	0.37	2.23	2.84	3.03	36.37
1915	5.60	4.56	0.13	2.70	1.26	1.37	10.16	13.22	2.48	2.58	3.14	6.37	53.57
1916	1.94	5.92	3.34	3.86	4.18	4.54	4.11	1.59	6.15	1.54	2.38	2.09	41.64
1917	2.74	1.47	2.60	2.06	5.02	6.01	2.47	3.17	0.94	9.06	2.33	2.61	40.48
1918	3.49	3.07	2.74	3.53	2.75	3.63	1.71	2.25	6.55	1.56	2.52	3.55	37.35
1919	2.14	2.72	6.48	2.21	8.50	0.87	3.04	4.14	4.46	3.02	5.73	1.96	45.27
1920	2.83	5.23	4.31	6.70	2.99	6.17	3.21	3.16	7.14	1.25	5.83	5.93	54.75
Av. 8 yrs.	3.20	3.51	3.78	3.69	3.88	3.14	3.62	4.25	4.03	3.38	3.57	3.62	43.67

RAINFALL AT CONCORD, MASS. Elevation, 139 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.60	2.90	4.21	4.63	2.82	1.98	2.33	3.71	0.12	1.73	2.57	3.30	33.90
1915	4.96	3.62	T	2.13	1.75	1.64	11.64	5.74	0.81	3.05	2.61	4.88	42.83
1916	1.35	5.16	3.28	4.43	2.91	4.70	3.74	2.08	2.16	1.05	2.07	2.57	35.50
1917	2.50	2.43	3.56	2.43	4.48	4.67	1.95	3.53	1.55	5.26	0.99	2.93	36.28
1918	3.15	2.25	2.88	2.92	2.43	3.44	3.73	2.14	8.86	0.96	2.59	3.19	38.54
1919	3.63	3.58	4.21	2.58	5.53	1.17	3.74	4.09	4.77	1.84	5.85	1.61	42.60
1920	2.87	6.06	3.85	5.65	2.69	6.04	1.82	1.51	4.42	1.06	5.19	5.36	46.52
Av. 30 yrs.	3.23	3.35	3.52	3.30	3.21	3.10	3.47	3.51	3.51	2.97	3.29	3.31	39.77

RAINFALL AT CUMMINGTON, MASS. Elevation, 1 400 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1903	...	...	...	3.86	0.64	11.06	4.25	5.23	1.72	4.60	1.92	4.17	....
1904	5.10	4.66	4.18	4.27	3.81	5.64	2.74	5.84	4.47	2.59	3.55	3.28	50.13
1905	5.59	1.77	2.93	2.64	1.58	3.70	5.12	5.85	5.75	2.69	2.40	3.50	43.52
1906	1.93	1.81	4.33	2.82	3.67	4.05	2.60	5.13	3.34	3.27	1.96	3.73	38.64
1907	2.57	2.02	2.23	2.19	3.09	4.47	...	...	...	...	...	...	....
1919	...	...	...	...	...	...	...	...	...	2.76	5.83	1.81	....
1920	2.03	4.72	4.64	6.43	1.79	6.00	3.11	3.63	6.89	1.55	6.70	6.08	53.57

RAINFALL AT DALTON, MASS. Elevation, 1 200 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.57	1.78	4.94	5.97	2.75	2.52	3.73	3.32	0.41	1.38	2.14	2.87	34.38
1915	4.03	5.21	0.17	2.29	1.69	3.38	10.86	6.57	2.89	1.95	1.96	6.73	47.73
1916	2.82	3.65	3.95	3.31	2.53	3.71	5.24	2.29	5.73	0.98	4.33	3.02	41.56
1917	3.60	2.47	3.95	1.70	2.38	4.12	2.84	2.02	0.91	6.84	0.62	1.81	33.26
1918	2.98	2.76	3.06	3.13	3.57	3.21	1.96	2.84	6.22	3.39	2.50	3.45	39.07
1919	2.39	2.15	5.15	2.05	7.20	1.20	4.56	4.25	5.02	3.65	5.03	1.92	44.57
1920	2.11	3.95	3.77	6.05	1.49	4.75	2.96	2.79	5.14	1.53	6.11	4.79	45.44
Av. 15 yrs.	3.20	2.97	3.60	3.39	3.50	2.79	3.89	3.59	3.82	3.30	3.11	3.18	40.34

RAINFALL AT DANVERS, MASS. Elevation, 100 feet.
(State Hospital.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1911	...	...	...	...	0.19	4.11	5.14	3.86	2.04	2.65	3.92	3.38	....
1912	2.89	2.82	4.52	4.27	5.37	0.24	4.07	2.18	2.54	1.70	3.30	4.54	38.44
1913	2.30	2.80	3.96	3.97	3.02	1.07	1.45	2.65	2.94	7.04	2.04	3.03	36.27
1914	2.99	3.15	3.45	6.72	2.51	1.30	2.51	2.47	0.17	1.34	2.90	2.45	31.96
1915	5.55	3.39	0.02	1.80	1.15	2.10	10.04	6.09	0.67	2.62	2.16	3.33	38.92
1916	1.16	3.92	2.70	4.49	3.96	5.33	3.85	1.97	2.70	1.11	1.88	2.25	35.32
1917	2.87	2.04	4.05	2.81	4.18	4.81	1.49	3.31	1.43	6.00	1.19	2.02	36.20
1918	2.69	2.79	1.73	4.38	0.85	2.81	2.10	2.16	8.05	0.90	2.21	2.98	33.65
1919	3.51	3.09	3.94	2.80	5.13	0.68	3.25	4.77	5.74	2.20	5.34	1.37	41.82
1920	2.16	5.72	3.27	6.15	4.25	5.57	1.38	1.93	4.30	0.96	5.62	4.29	45.60
Av. 9 yrs.	2.90	3.30	3.07	4.15	3.39	2.66	3.35	3.29	3.19	2.65	2.96	2.67	37.58

RAINFALL AT DUDLEY, MASS. Elevation, 450 feet.
(Stevens Linen Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.32	3.40	4.65	4.12	3.45	1.76	2.84	3.00	0.41	2.07	2.27	2.86	33.15
1915	6.11	5.08	0.10	1.00	2.34	1.77	6.81	6.33	1.63	2.44	1.89	4.53	40.03
1916	1.58	5.54	3.08	3.31	3.33	5.77	4.26	1.38	3.21	2.09	2.54	2.99	39.08
1917	3.22	3.34	4.23	1.62	4.15	5.10	1.45	7.33	1.35	5.93	0.61	2.21	40.54
1918	3.36	3.02	2.71	3.02	2.94	4.67	2.58	2.38	9.70	1.35	2.84	2.69	41.26
1919	3.95	3.28	4.89	3.49	4.52	3.40	3.89	3.55	6.10	2.45	5.22	1.98	46.72
1920	2.74	3.97	4.64	5.05	4.89	6.13	2.57	2.47	3.53	2.68	3.87	5.62	48.16
Av. 29 yrs.	3.31	3.54	4.16	3.30	3.40	3.27	3.43	3.81	3.73	3.20	3.42	3.60	42.17

RAINFALL AT DUDLEY, MASS. Elevation, 705 feet.
(Nichols Academy.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1884	...	...	...	...	...	...	...	3.24	1.06	1.03	2.14	...	....
1885	3.86	4.15	0.45	1.90	3.15	2.02	1.26	5.90	1.75	3.74	4.12	2.72	35.02
1886	3.15	5.12	2.98	1.64	2.77	1.29	4.81	3.04	2.20	1.73	3.66	4.06	36.45
1887	3.50	4.45	3.30	3.15	0.99	2.78	10.49	3.45	1.84	2.39	2.44	3.97	42.75
1888	2.92	3.09	6.77	2.46	5.18	2.31	1.48	5.24	7.57	6.26	5.68	5.33	54.29
1889	2.75	1.31	1.16	2.55	2.74	2.11	3.39	2.09	4.02	4.20	4.10	2.80	33.22
1890	1.69	3.00	6.60	2.10	5.60	1.70	3.57	5.67	5.33	5.19	0.88	3.34	44.67
1891	7.57	4.39	5.32	1.91	1.24	1.94	2.09	2.58	2.45	2.96	1.35	2.40	36.20
1892	4.92	2.06	2.91	0.58	4.74	2.07	2.84	4.74	2.58	1.49	4.77	1.64	35.34
1893	2.04	3.40	3.37	2.65	6.61	1.13	1.12	1.55	1.86	3.93	2.04	3.07	32.77
1894	2.01	3.52	1.29	2.73	3.52	0.31	1.61	2.02	2.23	2.32	1.77	3.30	26.63
1895	4.57	1.10	2.12	2.06	1.43	2.91	2.40	2.91	1.20	3.50	4.60	2.30	31.10
1896	1.25	4.50	4.60	0.90	1.80	2.80	5.10	2.55	5.90	2.70	1.60	1.62	35.32
1897	2.77	2.10	3.37	2.14	4.27	3.59	9.95	3.25	1.85	0.75	6.02	4.85	44.91
1898	2.62	3.55	2.37	6.03	2.65	4.15	5.87	5.77	**3.27**	4.80	5.72	**1.75**	43.53
1899	3.95	5.40	4.94	2.26	3.42	**4.03**	**4.11**	**1.84**	3.75	0.80	**2.39**	1.75	38.64
1900	3.53	6.00	6.67	1.63	4.05	...	...	...	...	...	...	...	...
Av. 15 yrs.	3.30	3.40	3.44	2.34	3.34	2.34	4.01	3.51	3.19	3.12	3.41	2.99	38.39

RAINFALL AT FALL RIVER, MASS. Elevation, 140 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.07	3.17	3.97	3.40	2.56	0.87	4.19	3.03	1.24	3.00	2.90	4.84	35.24
1915	9.28	4.11	0.08	1.68	2.05	2.23	2.28	5.33	1.81	3.48	3.04	4.73	40.10
1916	1.47	4.72	3.22	4.29	4 31	3.72	9.85	2.20	1.06	2.11	1.93	4.65	43.53
1917	2.44	2.91	5.08	3.33	4.98	4.79	1.33	3.03	2.89	4.67	0.37	2.03	37.85
1918	3.17	2.86	2.04	4.92	1.90	3.06	2.71	3.44	3.55	0.82	2.00	3.49	33.96
1919	5.76	3.80	4.15	3.07	4.23	1.89	5.21	6.49	6.87	2.18	3.95	2.91	50.51
1920	3.45	6.36	4.78	5.29	4.95	8.30	1.98	2.51	1.00	3.38	3.34	3.87	49.21
Av. 48 yrs.	4.45	4.07	4.59	4.04	3.58	3.02	3.39	3.93	3.13	4.04	4.36	3.96	46.56

RAINFALL AT FALL RIVER, MASS. Elevation, 200 feet.

(U. S. Weather Bureau.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1893	3.09	7.52	4.88	4.83	5.80	2.77	1.85	6.77	3.28	3.73	3.84	6.77	55.13
1894	3.43	4.89	2.45	3.79	4.32	0.90	3.24	1.89	4.76	7.61	3.41	5.41	46.10
1895	3.84	1.02	3.76	4.69	4.27	2.50	3.38	3.55	1.12	5.88	5.30	3.00	42.31
1896	2.32	5.82	5.64	1.20	2.87	4.23	4.42	3.87	8.03	3.31	3.38	2.07	47.16
1897	4.35	2.44	3.18	3.95	4.10	2.35	4.60	5.87	2.38	1.10	8.22	4.43	46.97
1898	4.67	6.12	3.07	5.15	4.96	0.88	5.55	7.43	1.25	11.05	8.04	2.30	60.47
1899	5.56	4.72	7.37	2.28	1.90	3.55	3.82	1.73	6.64	2.31	1 57	1.43	42.88
1900	4.15	5.86	4.62	2.28	5.50	1.47	3.19	2.17	3.92	4.92	4.26	2.81	45.15
1901	2.47	0.80	7.34	8.98	7.56	1.77	2.13	3.01	2.75	2.65	2.13	9.57	51.16
1902	2.39	5.82	5.50	3.39	1.02	3.52	1.72	0.68	3.05	4.11	1.48	6.76	39.44
1903	4.48	4.99	7.13	4.76	1.08	5.14	2.16	4.11	0.65	3.88	2.01	3.32	43.71
1904	5.41	3.99	2.60	9.41	2.84	3.22	2.12	4.26	2.14	1.57	2.20	3.92	43.68
1905	3.92	2.26	2.74	2.21	1.24	5.64	2.61	4.94	4.03	1.98	2.29	4.28	38.14
1906	3.67	3.97	6.88	2.99	3.89	4.29	4.07	2.61	2.92	3.76	2.47	4.33	45.85
1907	3.13	3.09	2.44	3.11	4.11	2.07	0.88	1.08	7.33	2.35	6.61	6.12	42.32
1908	3.96	3.93	3.52	1.26	4.74	2.09	2.20	4.89	1.04	5.88	1.05	4.05	38.61
1909	2.78	5.58	3.82	5.94	2.82	1.04	0.43	2.30	3.06	1.76	3.47	3.26	36.26
1910	5.72	4.55	1.86	1.80	2.12	4.01	2.54	3.66	2.46	1.74	3.54	2.99	36.99
1911	3.29	1.81	3.43	3.69	1.95	1.49	4.71	3.48	1.91	2.28	6.79	3.71	38.54
1912	4.39	2.94	8.73	3.57	3.94	0.23	1.21	4.60	1.92	1.19	4.66	5.95	43.33
1913	4.49	3.30	3.47	6.36	2.01	1.05	2.87	2.87	2.95	9.15	2.23	4.08	44.83
1914	3.38	3.78	4.26	3.73	2.41	0.70	3.93	2.73	1.28	3.31	2.77	5.31	37.59
1915	10.00	4.34	0.05	2.21	2.04	2.27	3.17	5.25	1.73	3.62	2.91	5.11	42.70
1916	1.48	5.14	3.77	4.78	4.78	3.90	11.47	2.03	1.28	3.01	3.14	3.71	48.49
1917	3.63	2.73	5.04	3.17	4.77	4.63	1.21	3.75	2.93	5.69	0.45	3.10	41.10
1918	4.01	3.56	2.46	5.51	2.00	3.24	2.51	3.98	4.42	1.08	2.32	4.08	39.17
1919	5.07	3.80	5.29	3.24	4.62	1.93	5.52	7.26	7.48	2.51	3.71	2.33	52.76
1920	3.54	7.39	5.12	5.87	5.48	8.89	2.28	2.17	1.34	2.73	3.47	3.86	52.14
Av. 28 yrs.	4.02	4.15	4.30	4.08	3.54	2.84	3.21	3.68	3.14	3.72	3.49	4.22	44.39

RAINFALL AT FALMOUTH, MASS. Elevation, 22 feet.

(Woods Hole.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1873	4.76	4.92	3.15	4.63	4.32	1.01	1.56	3.07	3.86	5.54	9.05	6.23	52.10
1874	3.92	2.73	1.10	9.32	3.45	4.47	2.26	3.80	2.03	0.61	3.36	4.18	41.23
1875	4.20	2.88	5.34	3.95	4.52	2.23	4.68	2.37	2.79	3.62	4.77	1.23	42.58
1876	2.11	6.02	5.12	5.03	1.43	1.37	3.13	0.99	5.88	0.94	11.70	4.49	48.21
1877	2.83	2.84	10.78	4.20	2.39	2.22	5.69	5.42	0.28	6.97	6.80	1.20	51.62
1878	5.47	3.43	6.23	5.09	4.28	2.23	2.69	6.65	1.50	4.85	4.60	3.27	50.29
1879	3.37	1.98	4.39	4.79	1.35	2.31	3.31	4.81	2.22	1.37	3.54	2.86	36.30
1880	1.69	2.13	3.73	2.85	0.88	1.71	3.77	5.39	1.27	3.18	1.69	3.03	31.32
1881	2.57	5.46	4.22	2.12	2.39	6.25	1.71	0.65	2.50	2.68	5.52	2.06	38.13
1882	4.22	...	...	...	...	...	...	...	...	...	...	...	....
1887	...	...	3.00	4.42	1.91	4.03	2.93	10.84	1.99	2.21	2.84	4.59	....
1888	3.66	1.79	4.63	1.69	5.59	1.35	5.03	1.36	11.27	3.61	6.22	3.25	49.45
1889	3.91	4.39	2.87	4.44	5.33	1.96	3.63	4.21	3.37	4.49	5.45	2.06	46.11
1890	2.36	2.84	8.39	2.78	2.72	5 25	2.55	4.65	4.71	9.79	1.31	3.90	51.25
1891	6.95	6.26	4.15	2.81	1.94	1.16	2.18	3.57	3.72	7.09	1.65	3.68	45.19

RAINFALL AT FALMOUTH, MASS.— *Continued.*

(Woods Hole.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1892	3.58	1.95	5.11	2.61	5.43	1.80	1.64	2.45	2.85	2.08	8.47	1.72	39.69
1893	3.53	7.18	6.09	5.26	5.02	2.61	2.88	6.27	2.99	1.66	2.94	5.67	52.10
1894	5.07	4.69	1.81	3.97	3.52	1.23	0.68	1.31	2.24	9.29	3.87	5.63	43.31
1895	4.00	1.02	3.87	3.20	3.44	2.04	4.42	3.34	1.22	2.90	4.61	3.35	37.41
1896	1.75	4.26	4.83	1.33	3.58	3.62	2.81	2.99	5.66	4.53	2.49	3.18	41.03
1897	3.46	1.96	2.83	2.73	3.02	2.05	5.30	3.23	0.93	1.92	7.34	4.18	38.95
1898	3.94	4.14	3.12	5.83	4.66	1.10	5.18	5.10	0.76	7.94	6.94	2.97	51.68
1899	3.25	4.10	8.44	2.42	1.58	3.35	3.36	2.91	3.53	1.91	1.67	1.52	38.04
1900	4.96	5.21	3.56	2.82	3.63	..	....	...	...	...	...	...	....
Av. 21 yrs.	3.64	3.67	4.77	3.86	3.37	2.44	3.26	3.55	3.12	4.14	4.95	3.32	44.09

RAINFALL AT FITCHBURG, MASS. Elevation, 625 feet.

(Dr. Jabez Fisher.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.28	2.29	3.68	3.93	2.18	1.31	2.76	2.79	0.16	1.60	1.98	3.37	28.33
1915	5.20	3.05	0.00	1.83	1.44	1.31	8.74	7.28	1.41	2.79	3.20	4.74	40.99
1916	0.69	4.99	3.06	3.12	4.51	6.65	4.25	2.01	*3.48	*0.94	*2.46	*2.47	38.63
Av. 52 yrs.	3.24	3.28	3.37	3.09	3.58	3.44	3.79	4.21	3.35	3.72	3.38	3.09	41.54

* Dr. Mason's record. Dr. Fisher died December, 1916.

RAINFALL AT FITCHBURG, MASS. Elevation, 550 feet.

(Dr. A. P. Mason.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.28	2.19	3.45	4.01	1.90	1.51	2.83	2.52	0.19	1.62	2.63	3.28	28.41
1915	4.73	3.05	T	1.83	1.46	1.31	10.30	6.49	1.19	2.68	2.68	4.74	40.46
1916	1.32	4.44	2.53	2.76	3.30	6.53	4.77	2.54	3.48	0.94	2.46	2.47	37.54
1917	2.54	2.31	2.73	1.66	2.68	4.78	2.11	2.74	0.72	4.42	0.84	2.86	30.39
1918	2.48	3.11	1.97	2.15	2.92	4.39	3.64	2.12	7.53	1.03	2.60	3.01	36.95
1919	3.48	2.21	5.55	2.08	5.39	0.92	3.86	2.93	5.44	2.51	5.36	1.61	41.34
1920	1.73	4.03	3.50	5.12	3.45	4.84	4.92	3.13	7.60	1.57	3.80	6.41	50.10
Av. 35 yrs.	3.36	3.39	3.68	3.09	3.34	3.17	3.96	4.07	3.82	3.43	3.28	3.60	42.19

RAINFALL AT FRAMINGHAM, MASS. Elevation, 160 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.69	3.80	4.38	4.82	2.82	2.02	2.76	3.50	0.18	1.56	2.44	3.36	35.33
1915	6.49	3.37	0.04	2.46	1.63	3.47	7.92	5.80	1.03	2.99	2.51	5.33	43.04
1916	1.50	5.93	3.95	4.09	3.54	4.65	5.11	2.00	1.69	1.45	2.25	3.13	39.29
1917	3.46	2.64	5.20	2.43	4.70	4.28	1.15	6.11	1.50	5.24	1.29	2.79	40.79
1918	3.34	3.72	2.43	4.53	1.03	3.57	4.06	1.44	8.29	1.04	2.59	3.73	39.77
1919	3.45	3.41	4.67	2.91	4.92	1.99	4.96	3.90	5.36	2.18	6.09	1.94	45.78
1920	3.29	6.89	4.72	5.23	3.75	7.18	1.88	1.78	3.35	1.02	5.92	5.32	50.33
Av. 45 yrs.	4.01	4.08	4.32	3.52	3.27	3.01	3.54	3.73	3.31	3.58	3.70	3.85	43.92

RAINFALL AT FRAMINGHAM, MASS. Elevation, 160 feet.

(A. N. Rogers.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	...	...	..	...	3.41	0.30	1.57	2.27	2.65	....
1915	4.04	3.32	0.00	1.99	1.00	2.28	10.08	5.14	0.94	2.72	2.13	3.86	37.50
1916	1.20	5.29	4.72	2.95	3.06	4.93	2.92	1.59	1.39	0.47	2.02	2.58	33.12
1917	2.89	3.24	4.42	2.32	4.84	4.28	1.03	5.23	1.16	4.71	0.76	2.89	37.77
1918	3.45	2.95	4.02	4.37	1.98	3.38	2.74	1.23	8.37	0.58	2.85	2.53	38.45
1919	3.76	2.12	4.53	2.49	4.46	1.84	3.69	3.88	5.79	2.03	6.15	2.05	42.79
1920	2.95	4.79	3.87	4.98	3.13	6.74	1.88	1.88	1.99	1.41	4.48	4.81	42.91
Av. 6 yrs.	3.05	3.62	3.59	3.18	3.08	3.91	3.72	3.16	3.27	1.99	3.07	3.12	38.76

RAINFALL AT GARDNER, MASS. Elevation, 1 110 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.98	2.78	5.35	4.86	2.60	3.40	2.53	4.45	0.20	1.38	2.42	4.45	37.40
1915	6.50	3.60	0.01	3.02	1.47	2.14	9.94	5.18	1.51	3.00	2.46	5.65	44.48
1916	1.38	4.65	2.97	3.63	3.71	5.95	4.52	2.67	3.41	1.43	2.66	3.23	40.21
1917	3.04	2.94	3.89	2.13	4.08	5.63	1.68	5.82	0.55	6.08	2.19	2.72	40.75
1918	3.04	4.00	2.02	3.49	1.24	4.80	2.42	3.11	6.18	1.07	2.82	3.34	37.53
1919	3.03	3.23	4.56	2.20	7.09	1.21	5.97	3.21	5.22	2.73	6.53	1.61	46.59
1920	2.58	5.29	3.78	5.77	3.54	4.52	3.13	4.23	6.84	0.99	5.25	5.99	51.91
Av. 14 yrs.	3.22	3.54	3.41	3.16	3.25	3.10	3.65	4.21	3.69	2.80	3.54	3.62	41.49

RAINFALL AT GLOUCESTER, MASS. Elevation, 40 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	**6.02**	2.88	0.00	1.64	2.22	1.41	8.52	4.98	1.99	3.19	4.06	4.46	41.37
1916	1.74	4.57	9.68	6.46	3.36	8.57	4.39	3.70	2.21	1.00	2.92	2.97	51.57
1917	3.84	2.43	3.61	3.11	5.05	5.67	1.19	5.60	2.15	5.31	0.84	3.15	41.95
1918	3.00	2.44	3.12	4.17	1.64	2.63	1.96	2.17	10.03	1.20	2.66	3.15	38.17
1919	4.92	3.98	4.41	2.76	5.95	1.62	2.06	4.17	6.07	3.04	6.50	1.60	47.08
1920	2.35	10.11	4.93	6.38	4.11	10.22	1.00	0.90	2.98	2.84	5.79	2.87	54.48
Av. 6 yrs.	3.65	4.40	4.29	4.09	3.72	5.02	3.19	3.59	4.24	2.76	3.79	3.03	45.77

RAINFALL AT GRANVILLE (WEST), MASS. Elevation, 1 200 feet.
(East Branch Shed, Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	...	...	...	...	...	...	3.07	3.44	2.89	4.56	4.27	4.36	....
1913	3.39	1.92	6.83	4.84	4.88	1.19	2.58	3.36	3.90	8.39	4.31	1.51	47.10
1914	2.61	1.31	4.20	4.13	3.16	3.04	2.88	1.38	0.25	2.28	2.54	3.25	31.03
1915	6.14	4.72	5.12	3.12	2.47	3.90	6.06	8.06	3.00	2.24	2.44	5.16	52.43
1916	0.68	4.54	2.02	2.55	1.15	2.95	**6.26**	**2.65**	5.04	1.17	3.78	1.64	34.43
1917	1.56	4.18	7.52	4.35	5.60	6.12	1.55	5.19	0.78	7.57	1.50	2.78	48.70
1918	2.50	2.38	2.83	3.80	2.00	3.00	2.00	3.09	4.40	3.64	1.01	3.95	34.60
1919	3.00	3.60	5.58	5.00	5.55	0.53	4.16	3.99	4.62	5.07	6.47	1.52	49.09
1920	0.70	5.20	2.20	6.20	2.98	5.63	5.75	5.97	5.55	0.10	5.90	4.85	51.03
Av. 8 yrs.	2.57	3.48	4.54	4.25	3.47	3.30	3.91	4.21	3.44	3.81	3.49	3.08	43.55

RAINFALL AT GRANVILLE, MASS. Elevation, 750 feet.
(Westfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.33	2.47	4.28	6.08	3.60	2.86	3.61	2.29	0.38	2.77	3.79	3.44	37.90
1915	6.93	5.46	0.21	2.79	2.64	3.23	8.42	8.55	2.41	2.40	3.82	3.25	50.11
1916	1.55	3.45	4.08	2.74	3.38	5.30	5.80	2.45	6.28	1.60	4.35	3.34	44.32
1917	3.45	3.25	3.98	1.84	5.93	2.35	4.20	6.55	0.77	9.60	1.07	3.70	46.69
1918	4.23	2.18	3.28	2.46	2.42	3.99	2.19	2.96	7.56	1.43	2.76	3.99	39.45
1919	2.30	3.36	6.65	2.60	7.42	2.06	4.43	2.45	4.71	1.80	6.45	2.19	46.42
1920	2.65	4.80	4.19	5.59	3.41	7.68	4.04	8.32	6.56	1.88	6.20	6.30	61.62
Av. 13 yrs.	3.44	3.81	3.80	3.76	4.10	3.21	3.84	4.86	3.86	3.94	3.74	3.38	45.74

RAINFALL AT GRANVILLE, MASS. Elevation, 950 feet.
(Borden Brook Reservoir, Springfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.32	4.14	6.60	6.13	2.44	2.33	3.61	2.27	0.19	2.31	3.75	4.60	40.69
1915	7.43	6.24	0.35	3.94	2.36	4.70	7.18	8.39	2.55	2.62	3.60	8.58	57.94
1916	2.40	6.79	5.45	4.19	3.64	5.85	6.26	2.65	6.70	1.56	4.44	3.70	53.63
1917	3.18	4.12	4.75	3.20	4.20	5.15	2.35	3.73	1.00	8.65	0.90	4.90	46.13
1918	3.40	3.82	2.83	3.51	2.02	2.35	2.65	4.06	6.83	1.47	2.92	3.83	39.69
1919	2.52	4.06	5.61	3.67	8.76	1.04	5.00	3.80	6.11	2.52	7.06	2.70	52.85
1920	3.34	3.92	4.32	6.08	2.83	8.76	3.90	4.09	9.43	1.07	7.95	5.94	61.63
Av. 7 yrs.	3.51	4.73	4.27	4.39	3.75	4.31	4.42	4.14	4.69	2.89	4.37	4.89	50.36

RAINFALL AT GREAT BARRINGTON, MASS. Elevation, 750 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	...	3.02	1.96	2.66	2.45	0.38	1.16	2.06	1.72	....
1915	5.11	4.83	0.00	1.86	2.02	3.16	8.18	6.64	1.58	2.50	1.84	6.07	43.79
1916	1.34	3.04	2.01	2.92	2.63	3.84	7.14	2.86	7.06	0.90	3.51	2.34	39.59
1917	2.35	1.77	2.19	2.31	5.31	3.78	5.43	3.57	1.04	5.52	0.93	2.15	36.35
1918	1.12	2.93	1.59	3.78	3.60	2.65	2.55	6.55	5.55	1.39	2.95	3.30	37.96
1919	1.38	3.70	4.04	2.25	5.60	1.10	4.20	2.18	3.22	3.27	5.14	2.08	38.16
1920	2.18	2.62	1.94	6.22	1.75	6.14	3.31	6.01	9.56	1.59	4.91	4.15	50.38
Av. 6 yrs.	2.25	3.15	1.96	3.22	3.49	3.45	5.14	4.64	4.67	2.53	3.21	3.35	41.06

RAINFALL AT GROTON, MASS. Elevation, 350 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.81	2.87	2.64	4.17	2.64	1.38	3.50	3.28	0.20	1.32	2.95	4.05	31.81
1915	4.77	3.13	0.01	1.76	1.76	2.55	7.60	6.52	1.35	2.86	2.60	4.80	39.71
1916	1.32	5.69	3.55	5.23	3.98	6.92	4.10	2.11	4.13	1.11	2.72	2.79	43.65
1917	3.38	2.20	4.28	2.06	4.00	4.69	1.16	3.79	1.02	5.04	1.80	3.08	36.50
1918	3.60	3.49	2.14	3.52	2.07	3.38	2.63	2.54	7.11	0.97	2.70	3.14	37.29
1919	3.34	3.16	4.70	2.45	5.52	1.28	4.02	3.41	5.17	2.47	5.58	1.77	42.87
1920	2.55	5.93	4.09	6.06	3.68	5.27	3.37	4.14	5.62	0.71	5.40	5.97	52.79
Av. 31 yrs.	3.50	3.60	3.81	3.52	3.67	3.50	3.63	3.94	3.92	3.62	3.52	3.60	43.83

RAINFALL AT HARDWICK (GILBERTVILLE), MASS. Elevation, 560 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1885	...	...	...	...	...	3.58	2.39	11.19	1.30	3.77	5.90	3.20	....
1886	5.94	5.26	3.68	1.84	3.58	2.08	5.09	3.39	4.61	2.00	5.78	5.41	48.66
1887	6.68	5.78	5.19	**2.98**	**1.13**	4.05	6.06	5.05	1.51	2.75	3.52	4.09	48.79
1888	3.88	4.36	6.65	3.17	4.26	**5.40**	2.63	4.94	9.84	5.14	5.18	5.22	60.67
1889	4.73	1.13	2.99	2.03	2.53	4.18	9.63	6.35	4.28	5.35	5.91	3.92	53.03
1890	2.38	3.06	7.17	3.00	6.09	2.17	4.76	7.96	6.76	7.94	1.68	3.75	56.72
1891	6.53	3.30	3.70	2.93	2.68	4.93	5.22	3.65	1.31	3.82	2.31	5.44	45.82
1892	5.48	1.81	3.29	0.69	6.81	2.92	7.15	7.40	1.99	0.73	5.51	1.39	45.17
1893	2.74	7.50	3.32	2.98	4.84	4.46	2.64	3.40	2.62	6.68	2.40	5.68	49.26
1894	3.24	3.55	1.11	3.77	3.22	...	...	...	...	...	2.32	...	....
1895	...	...	...	...	...	...	5.03	3.32	3.21	...	...	...	....
1919	...	...	...	...	...	...	...	3.32	5.93	2.64	6.11	2.07	....
Av. 8 yrs.	4.80	4.03	4.50	2.45	3.99	3.77	5.40	5.27	4.12	4.30	4.04	4.36	51.03

RAINFALL AT HAVERHILL, MASS. Elevation, 125 feet.

(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.17	2.38	3.82	6.03	2.30	1.38	1.62	3.58	0.25	1.10	1.77	2.47	28.87
1915	3.24	2.75	0.01	1.06	1.59	1.62	10.98	5.88	0.60	2.85	3.29	2.88	36.75
1916	1.56	4.13	3.09	4.19	5.02	6.60	4.91	1.78	1.99	0.88	1.89	2.82	38.86
1917	2.64	1.98	3.60	3.07	3.15	5.13	1.89	3.06	1.06	5.81	1.04	2.96	35.39
1918	2.23	1.93	1.94	3.19	2.03	3.50	7.13	2.25	7.58	1.34	2.70	2.05	37.87
1919	3.51	2.28	3.94	2.47	5.86	3.03	2.74	2.90	3.56	2.92	6.10	1.59	40.90
1920	1.62	4.90	3.72	4.62	2.99	4.82	2.70	2.92	5.26	1.58	5.76	4.37	45.26
Av. 26 yrs.	3.10	3.30	3.86	3.52	2.95	3.24	3.46	3.08	3.34	3.12	3.09	3.34	39.40

RAINFALL AT HINGHAM, MASS. Elevation, 70 feet.
(Henry W. Cushing.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.78	3.15	3.59	4.63	3.12	1.03	3.72	4.62	0.62	1.79	4.49	5.56	40.10
1915	7.66	3.86	T	2.21	2.16	1.64	6.32	5.85	0.70	2.67	2.50	4.63	40.20
1916	1.41	5.97	3.88	5.52	4.07	5.44	5.99	2.43	2.14	2.91	2.48	3.38	45.62
1917	3.74	0.92	4.74	3.69	5.32	5.54	2.01	8.54	2.33	6.86	0.47	2.56	46.72
1918	3.15	3.12	1.84	3.85	3.79	2.05	4.03	1.64	10.63	1.02	2.22	3.08	40.42
1919	4.12	3.41	4.73	3.32	5.29	3.34	5.07	7.25	6.29	2.98	5.55	2.30	53.65
1920	3.49	6.94	3.90	4.08	4.53	6.71	2.43	2.75	2.21	2.28	4.80	3.51	47.63
Av. 35 yrs.	3.99	4.02	4.08	3.67	3.48	3.04	3.85	3.79	3.85	4.08	4.00	3.97	45.82

RAINFALL AT HINGHAM, MASS. Elevation, 100 feet.
(Town gage, Hingham Water Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.21	3.18	5.43	5.04	3.44	1.03	3.88	4.06	0.75	1.94	4.34	6.07	42.37
1915	7.31	3.78	0.00	1.09	2.38	2.61	6.09	5.18	0.82	3.41	2.74	4.23	39.64
1916	1.63	5.72	4.14	5.43	4.06	6.11	5.07	2.71	2.18	2.70	1.03	4.22	45.00
1917	2.97	2.58	4.83	3.40	4.97	6.96	2.05	6.78	2.16	6.59	0.43	3.32	47.04
1918	3.39	2.36	3.54	4.36	2.44	2.33	4.32	1.72	9.19	0.74	2.04	3.60	40.03
1919	3.72	3.63	4.56	2.91	5.09	2.68	4.87	6.65	6.96	2.86	5.51	2.11	51.55
1920	3.46	7.36	4.18	4.94	4.55	6.75	2.02	2.94	3.68	1.42	5.63	3.86	50.79
Av. 24 yrs.	3.79	4.01	4.21	4.04	3.26	3.33	4.03	3.53	3.80	3.50	3.67	4.06	45.23

RAINFALL AT HINGHAM, MASS. Elevation, 150 feet.
(Accord Pond, Hingham Water Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	3.04	2.58	4.56	2.66	3.69	5.54	1.30	6.94	3.65	6.64	0.35	2.89	43.84
1918	3.11	2.65	2.75	4.10	3.66	2.64	4.51	1.43	10.62	0.50	1.92	3.60	41.49
1919	3.71	4.12	4.51	3.41	4.09	2.52	5.77	6.67	8.00	2.55	5.78	2.17	53.30
1920	3.28	7.19	4.48	3.84	3.55	4.88	3.09	1.62	3.65	1.31	4.32	4.03	45.24
Av. 4 yrs.	3.28	4.14	4.08	3.50	4.75	3.89	4.67	4.17	4.48	2.75	3.09	3.17	45.97

RAINFALL AT HOLDEN, MASS. Elevation, 750 feet.
(Jefferson, Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.61	4.05	4.75	5.36	3.50	2.20	4.02	5.30	0.19	1.93	3.46	4.03	42.40
1915	7.83	3.88	0.08	2.09	1.84	3.50	7.92	7.21	1.50	3.20	3.39	6.59	49.03
1916	1.77	6.43	3.99	3.78	4.24	6.61	6.53	1.78	4.31	1.53	3.43	3.07	47.47
1917	3.72	3.91	4.67	1.87	3.75	4.86	1.18	5.29	1.29	6.37	1.39	2.64	40.94
1918	3.25	5.27	3.07	3.58	0.86	4.73	2.67	3.05	6.61	2.05	3.47	4.08	42.69
1919	3.65	4.49	5.08	2.50	6.21	3.40	6.44	4.25	8.32	2.30	6.28	2.06	54.98
1920	3.67	7.33	5.10	6.52	3.54	6.61	4.84	2.56	6.32	0.70	5.38	6.32	58.89
Av. 24 yrs.	3.90	4.19	4.36	3.85	3.48	4.03	4.29	4.31	3.96	3.42	3.65	4.34	47.78

RAINFALL AT HOLDEN, MASS. Elevation, 1 100 feet.
(Kendall Reservoir, Worcester Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	...	...	...	...	...	...	...	...	...	...	...	2.95	....
1913	2.98	2.41	5.75	4.50	4.19	0.94	2.23	2.11	5.53	6.67	2.60	3.23	43.14
1914	2.50	3.36	4.67	4.75	3.22	1.97	3.52	4.29	0.15	1.59	3.21	3.00	36.23
1915	6.82	4.40	0.09	1.49	1.75	1.70	8.71	5.92	1.58	3.09	2.53	5.70	43.78
1916	1.82	5.89	4.11	2.89	3.91	6.07	6.48	1.85	3.64	1.62	2.56	3.04	43.88
1917	3.18	4.02	4.67	1.63	3.71	4.35	1.17	6.92	1.18	7.94	0.78	3.02	42.57
1918	1.88	1.93	2.46	3.49	0.96	4.63	4.08	2.97	8.07	2.19	3.62	3.26	39.54
1919	3.83	3.69	6.27	2.81	6.68	2.03	5.65	4.28	8.54	2.72	7.10	2.48	56.08
1920	3.37	5.78	4.97	6.17	4.31	5.47	4.54	1.97	8.54	0.82	4.71	5.50	56.15
Av. 8 yrs.	3.30	3.94	4.12	3.47	3.59	3.39	4.55	3.79	4.65	3.33	3.39	3.65	45.17

RAINFALL AT HOLDEN, MASS. Elevation, 1 000 feet.
(Kettle Brook, Worcester Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.15	4.08	5.35	5.21	3.31	1.97	3.76	4.46	0.03	1.92	2.68	3.70	38.62
1915	6.31	4.39	0.10	1.47	2.20	1.69	10.02	6.78	1.59	3.18	2.90	5.79	46.42
1916	1.74	7.06	3.86	4.04	4.02	6.29	7.31	1.78	3.63	1.80	2.42	3.86	47.81
1917	2.89	3.73	4.37	1.69	4.47	4.10	1.35	6.89	1.10	7.70	0.66	2.56	41.51
1918	3.59	3.30	3.24	1.89	2.22	4.58	4.51	2.22	7.85	1.98	3.08	2.71	41.17
1919	2.78	3.65	6.25	2.86	6.00	2.54	7.59	4.42	7.70	2.36	6.44	2.16	54.75
1920	3.57	6.36	4.68	5.59	4.85	6.53	4.83	1.85	7.93	0.70	5.55	6.47	58.91
Av. 16 yrs.	3.40	4.00	3.92	3.52	3.87	3.44	4.42	4.04	4.51	3.46	3.56	3.69	45.83

RAINFALL AT HOLDEN, MASS. Elevation, 750 feet.
(Reservoir No. 2, Worcester Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.82	3.18	4.89	4.93	2.68	2.05	3.53	4.47	0.20	1.73	2.88	3.42	36.78
1915	6.78	4.67	0.09	1.32	2.00	1.95	10.11	5.39	1.37	2.83	2.40	5.05	43.96
1916	2.01	7.09	4.25	3.27	3.38	5.79	6.21	2.12	3.50	1.91	3.52	3.23	46.28
1917	3.68	4.39	4.73	1.81	4.60	4.54	1.57	6.56	1.36	6.94	0.84	2.75	43.77
1918	3.49	3.64	3.43	3.17	2.17	4.79	5.10	2.26	8.96	2.02	3.45	4.02	46.50
1919	3.41	3.89	6.14	3.16	6.45	2.29	6.84	4.49	7.04	2.70	6.80	2.30	55.51
1920	3.28	4.91	5.08	6.50	4.38	6.66	4.35	1.54	7.78	1.01	5.68	6.13	57.30
Av. 35 yrs.	3.74	3.77	4.16	3.40	3.59	3.31	4.24	4.01	4.03	3.73	3.88	3.81	45.67

NOTE. — Gage at Reservoir No. 1 discontinued in 1910.

RAINFALL AT HOLYOKE, MASS. Elevation, 90 feet.
(Holyoke Water Power Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.98	5.11	5.00	5.67	2.91	2.45	2.86	3.03	0.19	2.36	3.34	3.05	37.95
1915	6.03	5.40	0.11	2.08	2.68	1.97	7.17	8.62	2.17	2.52	2.30	5.90	46.95
1916	1.50	5.61	3.79	4.04	3.07	5.36	6.79	1.50	3.88	1.13	2.84	3.72	43.23
1917	3.25	3.25	3.91	1.74	3.91	4.65	5.67	3.93	0.67	5.69	0.82	3.23	40.72
1918	4.41	2.14	3.40	2.47	2.49	4.65	1.59	4.01	7.07	1.22	2.70	3.91	40.06
1919	2.35	3.15	6.53	2.80	6.87	2.40	6.34	3.11	4.83	2.01	5.96	2.12	48.47
1920	2.92	5.63	4.06	5.73	4.25	6.59	4.51	6.66	4.74	3.55	5.43	6.00	60.07
Av. 23 yrs.	3.47	3.83	4.33	3.72	3.68	3.36	4.10	4.31	3.75	3.50	3.06	3.79	44.90

RAINFALL AT HOLYOKE, MASS. Elevation, 230 feet.
(Whiting Street Reservoir, Holyoke Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.43	1.57	4.34	4.58	2.80	2.29	3.68	3.74	0.27	2.32	3.18	3.01	35.21
1915	5.68	5.06	0.10	3.61	1.71	4.40	6.91	7.26	1.65	2.46	2.80	4.37	46.01
1916	1.65	4.56	2.53	3.15	2.88	7.01	5.16	2.46	5.93	1.00	3.41	2.99	42.73
1917	3.42	2.77	3.88	1.75	4.17	4.21	2.93	5.30	0.64	6.68	0.74	2.74	39.23
1918	3.80	2.39	3.32	2.28	2.59	4.63	1.83	2.67	8.44	1.22	3.14	3.67	39.98
1919	2.08	3.11	5.83	2.52	6.91	2.14	5.75	3.27	4.31	2.20	7.16	1.93	47.21
1920	1.93	6.84	3.30	5.28	4.40	6.69	2.80	5.81	6.34	2.67	4.78	6.16	57.00
Av. 14 yrs.	3.12	3.55	3.46	3.42	3.86	3.34	3.43	4.12	3.91	3.25	3.26	3.27	41.99

RAINFALL AT HOLYOKE, MASS. Elevation, 330 feet.
(Ashley Pond, Holyoke Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.44	3.74	4.44	5.30	2.88	2.72	2.57	3.35	0.24	2.43	3.58	3.15	36.84
1915	6.09	5.10	0.10	2.43	1.60	1.90	7.84	9.53	2.55	2.37	3.17	5.31	47.99
1916	1.40	4.50	2.61	3.30	2.97	6.07	6.26	2.55	3.98	1.21	3.21	2.73	40.79
1917	3.32	2.73	3.73	1.78	4.28	5.61	3.18	3.76	0.48	7.46	0.85	2.64	39.82
1918	3.74	2.08	3.15	2.26	2.27	4.65	2.19	2.94	7.65	1.15	2.91	3.55	38.54
1919	2.08	3.08	5.98	2.50	6.53	1.98	6.44	2.95	4.57	2.01	6.22	1.89	46.23
1920	1.89	5.34	3.06	4.92	3.39	6.27	3.13	5.84	5.96	2.05	4.78	5.67	52.30
Av. 14 yrs.	3.09	3.63	3.50	3.30	3.35	3.24	3.63	4.27	3.64	3.38	3.39	3.34	41.76

RAINFALL AT HOLYOKE, MASS. Elevation, 450 feet.

(High Service Reservoir, Holyoke Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.61	3.63	4.50	5.35	3.02	2.86	2.42	3.32	0.26	2.39	3.28	3.11	36.75
1915	5.10	4.61	0.08	2.45	1.91	2.91	8.37	8.18	2.49	2.32	3.38	4.82	46.62
1916	1.42	4.32	2.42	3.01	3.13	5.99	5.74	2.50	4.01	1.09	3.34	2.81	39.78
1917	3.26	2.70	3.67	2.01	4.44	6.08	3.12	3.87	0.51	8.36	0.80	2.42	41.24
1918	2.96	2.04	3.23	2.07	2.09	4.45	2.07	2.04	7.50	0.95	2.54	3.39	35.33
1919	2.14	3.11	5.87	2.66	6.47	1.99	6.61	3.05	4.58	1.95	6.30	1.80	46.53
1920	1.81	5.06	3.21	5.32	3.55	6.51	2.99	5.50	6.15	2.28	4.51	5.97	52.86
Av. 14 yrs.	2.96	3.50	3.48	3.33	3.76	3.35	3.53	4.01	3.58	3.46	3.32	3.19	41.47

RAINFALL AT IPSWICH, MASS. Elevation, 30 feet.

(Willowdale.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1911	...	...	...	...	0.26	3.36	7.08	4.49	2.17	3.20	4.08	3.65	....
1912	4.11	2.54	4.64	3.69	4.38	0.36	3.57	2.05	2.43	1.77	3.00	4.92	37.46
1913	3.09	2.90	4.14	4.04	3.03	2.60	1.43	3.09	2.85	7.47	1.95	3.66	40.25
1914	3.69	4.04	4.63	6.99	2.94	1.45	3.00	2.29	0.31	1.56	3.12	3.53	37.55
1915	5.73	3.46	0.15	2.84	1.36	2.44	9.88	5.66	0.80	3.08	2.54	4.68	42.62
1916	1.38	5.23	4.12	5.73	3.77	5.96	4.52	3.24	2.40	1.05	2.56	3.11	43.07
1917	3.52	2.41	4.15	2.96	3.82	5.53	2.58	3.11	1.80	5.09	1.69	2.70	39.36
1918	3.39	3.13	1.95	4.42	0.85	2.87	4.05	3.16	7.46	1.13	2.47	3.61	38.49
1919	3.92	3.40	4.54	2.57	5.48	1.22	3.00	4.78	5.72	2.72	6.19	1.67	45.21
1920	3.31	10.95	3.87	5.95	4.13	5.50	1.18	2.49	4.89	1.00	6.59	4.12	53.98
Av. 9 yrs.	3.57	4.23	3.58	4.35	3.31	3.10	3.69	3.32	3.18	2.76	3.35	3.55	41.99

RAINFALL AT LAKE COCHITUATE, MASS. Elevation, 140 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.53	4.11	4.41	4.93	2.71	1.59	3.17	3.62	0.27	1.69	2.45	3.38	35.86
1915	6.57	3.88	0.01	2.82	1.59	3.51	8.38	5.72	0.88	2.93	2.58	5.48	44.35
1916	1.52	5.66	4.62	4.12	3.20	5.45	3.89	1.75	1.30	1.28	2.18	3.18	38.15
1917	3.28	2.81	4.82	2.67	4.89	4.33	1.02	5.79	1.77	6.33	1.28	2.70	41.69
1918	3.26	3.80	2.26	4.61	1.10	3.34	3.64	1.41	8.58	0.92	2.57	3.55	39.04
1919	3.56	3.38	4.72	2.68	4.82	1.90	4.94	3.95	5.94	2.19	6.04	1.95	46.07
1920	3.25	7.01	4.28	5.61	2.96	7.73	1.81	1.58	3.88	1.21	5.96	5.47	50.75
Av. 69 yrs.	3.82	3.82	4.15	3.82	3.59	3.25	3.87	4.32	3.59	3.84	4.03	3.64	45.74

RAINFALL AT LAKEVILLE, MASS. Elevation, 60 feet.

(Assawompsett Pond, Taunton Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.71	3.69	3.96	3.85	2.41	1.00	3.67	2.61	1.40	2.39	3.35	5.26	36.30
1915	9.35	4.40	0.03	1.81	2.42	1.57	3.09	5.40	1.44	3.71	1.89	5.16	40.27
1916	1.88	4.31	3.09	4.35	4.78	4.58	9.06	0.71	1.43	2.81	1.95	4.61	43.56
1917	3.10	2.64	6.03	3.17	5.44	5.25	1.97	3.01	2.73	4.84	0.31	2.41	40.90
1918	3.37	3.11	2.22	4.97	1.42	3.59	3.44	2.45	3.80	0.58	2.65	3.71	35.31
1919	5.02	4.03	5.05	4.41	5.63	1.86	4.94	7.55	7.73	2.13	4.81	3.08	56.24
1920	3.20	7.86	5.03	5.42	5.14	7.93	2.26	2.58	3.84	1.94	3.89	3.98	53.07
Av. 27 yrs.	3.98	3.90	4.28	3.92	3.69	3.12	3.32	3.14	3.57	3.78	3.66	4.02	44.38

RAINFALL AT LAWRENCE, MASS. Elevation, 51 feet.
(Essex Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.37	3.18	4.48	5.36	2.35	1.28	2.43	3.92	0.18	1.19	2.10	2.96	33.10
1915	4.42	3.41	T	0.84	2.83	1.35	12.72	6.15	1.11	3.10	3.55	5.27	44.78
1916	1.81	5.45	3.41	4.48	4.74	6.58	4.18	2.80	2.70	0.92	2.30	3.10	42.47
1917	2.95	2.42	4.26	2.68	3.23	4.78	1.93	4.42	1.13	5.22	1.02	3.22	37.26
1918	3.01	2.44	2.62	2.79	2.05	3.44	7.63	2.14	7.97	1.27	3.09	3.72	42.17
1919	3.44	2.55	4.59	3.68	5.61	1.97	2.67	2.60	4.49	3.19	5.71	1.60	42.10
1920	2.14	6.41	4.21	5.78	3.05	4.70	2.79	2.55	3.95	2.75	4.63	5.56	48.52
Av. 65 yrs.	3.62	3.33	3.90	3.42	3.51	3.14	3.77	4.04	3.27	3.37	3.49	3.47	42.33

RAINFALL AT LAWRENCE EXPERIMENT STATION. Elevation, 45 feet.
(State Department of Public Health.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.11	2.78	4.03	5.92	2.39	1.36	2.60	3.93	0.26	1.21	2.56	2.87	33.02
1915	4.95	2.93	0.00	1.56	1.04	1.25	11.84	6.15	1.08	3.22	2.95	5.23	42.20
1916	1.57	5.01	4.46	5.04	4.54	6.38	4.13	2.32	2.07	0.93	2.30	3.20	41.95
1917	3.23	2.02	4.32	2.88	2.94	4.20	1.91	2.92	1.18	5.60	1.08	2.54	34.82
1918	2.85	3.00	1.99	4.30	1.21	3.44	5.89	1.91	6.59	1.35	3.12	3.48	39.13
1919	3.76	2.93	4.37	2.83	5.89	1.84	2.65	3.08	4.86	3.14	6.04	1.89	43.28
1920	2.66	7.23	4.23	6.36	2.32	5.22	2.83	1.99	4.69	1.23	5.73	5.43	49.92
Av. 17 yrs.	3.32	3.40	3.42	3.88	2.80	3.29	3.86	3.06	3.35	2.60	3.27	3.51	39.76

RAINFALL AT LEICESTER, MASS. Elevation, 800 feet.
(Lynde Brook Reservoir, Worcester Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.46	2.88	5.74	5.41	2.95	1.97	3.24	3.66	0.11	1.79	2.91	3.54	37.66
1915	6.30	4.21	0.11	1.51	1.76	1.70	10.13	6.41	1.10	2.77	2.37	5.30	43.67
1916	1.78	6.73	3.92	3.69	3.52	5.82	6.39	1.76	2.96	1.53	2.76	2.75	43.61
1917	2.91	3.08	4.06	1.64	3.83	3.91	1.53	7.82	0.71	6.00	0.55	3.02	39.06
1918	3.87	2.89	3.62	2.13	2.07	4.04	4.23	2.06	7.75	1.66	2.88	2.44	39.64
1919	3.98	3.24	6.11	2.79	5.67	2.06	5.30	3.47	6.81	2.09	6.06	2.15	49.73
1920	3.21	5.35	5.35	5.96	4.23	6.69	3.23	1.41	7.82	0.72	6.08	6.61	56.66
Av. 46 yrs.	3.53	3.50	4.16	3.25	3.17	3.10	4.11	4.08	3.50	3.63	3.59	3.54	43.16

RAINFALL AT LEOMINSTER, MASS. Elevation, 500 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.96	2.71	4.68	4.92	2.64	1.97	3.28	3.00	0.18	1.83	2.81	4.60	35.58
1915	5.87	3.71	0.02	1.73	1.61	1.64	9.61	7.41	1.58	2.81	3.01	4.57	43.57
1916	1.51	5.80	2.95	3.73	4.32	7.00	5.43	2.01	4.79	1.24	3.12	3.00	44.90
1917	3.15	3.03	3.41	2.11	3.76	5.05	2.14	3.82	0.90	5.95	1.01	3.04	37.37
1918	3.02	3.38	2.26	1.95	2.73	4.37	3.17	2.19	7.07	1.09	2.88	3.30	37.41
1919	3.46	3.02	5.70	2.27	6.11	1.24	4.14	4.17	5.73	2.55	6.33	1.86	46.58
1920	2.27	4.82	3.42	6.26	3.79	5.61	4.12	5.13	6.04	1.64	5.55	6.87	55.52
Av. 36 yrs.	3.57	3.64	3.78	3.30	3.68	3.42	4.08	4.24	3.86	3.57	3.61	3.65	44.40

RAINFALL AT LINCOLN, MASS. Elevation, 187 feet.
(Baker's Bridge.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.70	1.88	4.27	4.87	2.91	2.16	2.39	2.96	0.16	1.84	2.63	2.87	31.64
1915	4.84	3.51	T	1.44	1.93	1.87	10.35	5.76	0.96	3.58	2.79	3.78	40.81
1916	1.10	4.21	2.68	4.27	3.05	4.96	4.10	1.82	2.21	1.09	2.20	2.34	34.03
1917	2.61	1.86	2.88	3.09	5.07	4.20	1.50	2.56	0.73	4.36	1.22	2.40	32.48
1918	2.52	1.84	2.77	2.32	2.56	3.56	4.22	1.79	8.20	0.95	2.74	3.19	36.66
1919	2.75	2.81	3.75	1.85	5.62	1.22	5.46	4.35	5.15	1.94	6.07	1.24	42.21
1920	2.15	6.84	3.31	5.19	3.22	6.33	2.32	1.15	4.40	1.46	5.58	4.99	46.94
Av. 15 yrs.	2.76	2.93	3.01	3.13	3.40	2.91	3.72	2.94	3.39	2.46	3.19	2.94	36.78

RAINFALL AT LITTLETON, MASS. Elevation, 325 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1918	3.38	2.78	1.88	3.36	1.29	3.32	2.92	1.58	7.97	1.13	2.48	3.01	35.10
1919	3.18	2.95	4.96	2.72	5.88	1.26	4.75	3.11	4.47	2.75	6.01	1.89	43.93
1920	2.09	4.16	3.75	5.90	3.53	5.72	3.45	2.91	7.11	0.34	4.92	5.37	49.25
Av. 3 yrs.	2.88	3.30	3.53	3.99	3.57	3.43	3.71	2.53	6.52	1.41	4.47	3.42	42.76

RAINFALL AT LOWELL, MASS. Elevation, 80 feet.

(Merrimack Manufacturing Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.59	1.57	4.49	4.59	2.10	1.22	2.26	2.71	0.12	1.03	2.26	2.91	27.85
1915	3.78	3.41	0.00	1.61	1.48	1.43	10.21	5.77	0.98	2.45	2.77	4.22	38.11
1916	1.39	5.35	2.60	4.14	3.59	5.84	5.65	2.22	3.51	0.88	2.31	2.59	40.07
1917	2.85	1.86	3.37	2.24	3.26	4.44	1.42	3.41	1.29	4.24	1.10	2.47	31.95
1918	2.95	1.91	2.41	2.56	2.10	3.02	3.80	2.00	7.73	0.87	2.74	3.05	35.14
1919	3.27	2.54	4.10	2.27	4.71	0.70	2.94	1.80	4.07	2.62	5.13	1.36	35.51
1920	1.97	5.50	3.49	5.47	2.85	3.82	2.88	3.03	2.74	3.56	3.77	5.29	44.37
Av. 95 yrs.	3.15	3.13	3.51	3.46	3.44	3.25	3.58	4.15	3.33	3.49	3.66	3.34	41.49

RAINFALL AT LOWELL, MASS. Elevation, 100 feet.

(Proprietors Locks and Canals.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.42	4.44	4.98	5.90	2.54	1.66	2.77	3.61	0.12	1.17	2.58	3.21	36.40
1915	4.53	3.52	0.01	2.24	1.79	1.94	11.71	7.60	0.99	2.98	3.23	5.65	46.19
1916	1.56	6.10	3.68	5.47	4.29	7.20	6.17	2.25	3.66	1.05	2.53	3.16	47.12
1917	2.73	2.54	4.42	2.87	4.18	5.25	1.68	3.69	1.37	5.04	1.12	3.66	38.55
1918	3.37	2.25	2.78	2.99	2.36	2.71	2.88	2.06	7.71	0.89	2.24	3.19	35.43
1919	3.29	3.00	4.09	2.75	6.17	1.98	3.24	2.96	4.25	2.94	6.10	1.85	42.62
1920	2.54	6.53	4.60	6.24	3.36	4.69	2.85	2.78	6.46	0.78	5.12	5.94	51.89
Av. 66 yrs.	3.86	3.83	4.13	3.74	3.55	3.34	3.72	4.17	3.41	3.43	3.66	3.75	44.59

RAINFALL AT LUDLOW, MASS. Elevation, 410 feet.

(Ludlow Reservoir, Springfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.65	1.97	3.63	3.78	3.17	1.74	2.79	3.08	0.42	1.85	1.87	2.56	29.51
1915	5.82	3.09	0.07	1.80	1.61	1.73	6.81	5.73	1.96	2.00	1.74	3.99	36.35
1916	1.60	5.23	3.58	3.34	3.18	4.21	3.97	2.66	4.97	1.14	2.57	3.51	39.96
1917	2.18	2.77	2.63	1.34	3.06	3.64	1.83	4.67	0.91	4.58	0.59	2.95	31.15
1918	2.47	2.58	1.93	2.10	2.59	4.11	1.59	3.80	4.83	1.32	1.99	2.21	31.52
1919	1.84	3.37	3.65	2.18	2.91	2.13	6.24	1.64	5.27	1.87	4.11	1.86	37.07
1920	1.96	2.77	2.31	4.02	3.04	4.13	5.31	2.58	4.60	0.69	3.33	4.83	39.57
Av. 45 yrs.	3.25	3.15	3.77	3.06	3.27	3.29	4.44	3.93	3.55	3.37	3.11	3.37	41.56

RAINFALL AT LUDLOW, MASS. Elevation, 410 feet.

(Fillers, Springfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.57	5.14	3.56	3.38	2.98	4.14	3.87	2.50	5.15	1.01	2.59	3.51	39.40
1917	2.24	2.60	2.75	1.28	2.88	3.51	1.80	5.30	1.05	3.98	0.57	2.57	30.53
1918	2.05	2.65	1.24	1.93	2.57	4.70	1.71	3.93	5.51	1.34	1.99	2.59	32.21
1919	2.17	3.40	3.85	2.10	3.78	2.63	6.27	2.04	5.58	2.25	4.93	1.77	40.77
1920	1.79	2.30	2.08	4.26	3.15	4.97	5.58	3.19	5.68	0.82	3.92	4.85	42.59
Av. 5 yrs.	1.96	3.22	2.69	2.59	3.07	3.99	3.84	3.39	4.59	1.88	2.80	3.08	37.10

RAINFALL AT LYNN, MASS. Elevation, 40 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.47	2.80	3.98	6.23	2.70	2.20	3.04	3.40	0.57	1.56	2.71	3.07	35.73
1915	5.60	3.57	0.04	2.11	1.68	4.50	9.04	6.97	0.99	3.09	2.32	4.44	44.35
1916	1.07	4.50	3.76	4.24	3.42	5.62	3.73	2.77	1.73	0.93	1.70	2.88	36.35
1917	3.03	1.84	3.80	2.72	4.96	4.70	1.50	4.81	1.86	5.02	1.07	2.04	37.35
1918	2.74	3.04	2.10	4.35	0.73	2.01	2.89	1.70	10.25	0.62	1.91	4.01	36.35
1919	3.19	3.05	3.71	2.02	4.85	0.79	4.58	5.16	5.80	2.77	5.01	1.35	42.28
1920	2.68	6.50	3.66	5.10	5.33	6.55	1.66	2.49	2.59	1.34	5.46	2.92	46.28
Av. 48 yrs.	3.63	3.55	3.84	3.47	3.31	3.03	3.32	3.75	3.22	3.50	3.53	3.28	41.43

RAINFALL AT LYNN, MASS. Elevation, 70 feet.
(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.17	2.65	3.59	6.18	2.42	2.19	3.11	3.34	0.47	1.47	2.59	3.69	34.87
1915	5.80	3.17	0.01	1.95	1.96	4.37	9.07	6.38	2.16	2.82	2.28	4.16	44.13
1916	1.22	4.23	2.42	4.11	3.54	5.74	4.24	2.47	2.13	0.78	1.62	2.35	34.85
1917	3.24	1.77	3.32	2.38	3.63	4.33	1.75	4.31	1.70	4.71	1.03	1.99	34.16
1918	2.78	3.28	1.82	4.37	0.57	1.98	2.66	2.43	10.29	1.01	1.79	3.95	36.93
1919	2.93	3.13	4.09	2.54	4.98	0.79	5.02	5.65	5.61	2.79	5.02	1.36	43.91
1920	2.39	4.98	3.49	5.73	5.35	6.60	1.69	2.10	2.99	0.97	4.73	4.03	45.05
Av. 40 yrs.	3.25	3.20	3.31	3.42	3.23	3.11	3.22	3.83	3.10	3.22	3.25	3.14	39.28

RAINFALL AT MANCHESTER, MASS. Elevation, 20 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	2.69	2.95	3.50	4.95	3.44	0.90	2.32	2.60	2.78	6.24	2.24	3.44	38.05
1914	3.99	3.19	3.87	5.94	2.69	1.86	2.77	2.49	0.73	1.42	3.84	3.99	36.78
1915	5.73	3.03	0.10	1.78	1.61	1.53	9.81	5.63	1.30	3.64	3.16	4.38	41.70
1916	1.34	4.26	3.75	6.33	3.21	6.41	4.17	2.41	2.52	0.91	2.38	3.11	40.80
1917	3.47	2.11	3.77	3.45	4.67	5.80	1.17	4.72	2.20	5.00	1.41	2.96	40.73
1918	2.99	3.20	2.06	4.59	0.68	2.56	3.18	2.27	9.03	1.19	2.32	3.64	37.71
1919	3.91	3.47	4.15	2.61	5.65	1.52	3.37	4.61	6.00	3.01	5.74	1.79	45.83
1920	2.17	6.98	3.76	5.54	4.45	6.39	1.19	1.30	4.43	0.98	5.20	3.76	46.15
Av. 8 yrs.	3.29	3.65	3.12	4.40	3.30	3.37	3.50	3.25	3.62	2.80	3.29	3.38	40.97

RAINFALL AT MARLBOROUGH, MASS. Elevation, 450 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1900	**5.03**	**11.73**	**3.43**	**2.59**	**3.79**	3.01	2.96	2.42	3.74	3.04	6.37	2.33	50.44
1901	1.65	1.21	5.71	8.00	7.40	1.22	5.14	3.66	3.19	3.03	2.86	8.31	51.38
1902	1.97	4.86	4.52	3.80	2.14	2.26	3.51	3.55	4.28	4.56	1.03	5.66	42.14
1903	3.08	3.69	6.60	2.71	1.23	10.85	2.40	3.18	2.88	4.40	1.76	2.82	45.60
1904	3.58	2.06	2.17	8.16	2.76	2.86	2.32	3.75	4.79	1.26	1.34	2.50	37.55
1905	4.23	1.64	2.99	2.67	1.15	5.24	6.34	2.76	6.37	1.34	2.04	3.31	40.08
1906	2.28	2.58	4.88	2.53	6.07	2.91	6.62	3.71	2.71	2.83	2.75	3.75	43.62
1907	2.60	1.23	1.75	2.49	3.05	3.27	1.74	1.21	8.69	4.58	5.26	4.06	39.93
1908	3.20	3.68	2.67	2.12	5.08	0 86	3.53	6.49	0.87	2.68	1.00	2.51	34.69
1909	3.36	5.33	3.31	4.62	2.64	2.01	2.67	2.94	4.45	1.18	2.83	2.65	37.99
1910	4.68	3.79	1.07	2.52	1.36	3.94	1.28	2.20	2.89	1.99	4.09	1.91	31.72
1911	2.72	2.27	3.22	2.27	0.64	3.10	3.07	4.97	2.87	3.94	4.52	3.41	37.00
1912	2.42	2.46	5.63	4.45	5.61	0.33	2.20	2.71	1.76	2.29	3.33	4.54	37.73
1913	2.42	3.15	5.61	4.28	4.25	1.27	2.37	1.81	4.50	5.90	2.76	2.65	40.97
1914	2.18	3.32	4.13	4.07	2.69	1.83	4.52	4.76	0.19	1.73	3.12	2.62	35.16
1915	5.21	3.06	0.03	1.30	1.60	2.76	8.79	2.91	1.03	3.41	2.70	4.23	37.03
1916	1.11	4.58	2.95	4.07	3.47	5.36	4.35	1.81	2.40	1.38	2.77	2.74	36.99
1917	2.68	2.43	3.61	1.67	4.54	4.35	0.96	5.05	2.28	5.49	0.86	2.99	36.91
1918	2.88	2.43	2.76	3.05	2.24	3.72	4.03	2.32	8.80	1.21	2.56	2.51	38.51
1919	4.28	2.94	4.80	2.60	4.43	3.26	4.78	2.81	4.30	2.04	5.44	1.84	43.52
1920	2.01	4.14	3.16	5.18	3.67	6.08	2.49	2.18	3.71	0.85	5.37	4.30	43.14
Av. 21 yrs.	3.03	3.46	3.57	3.58	3.33	3.36	3.62	3.20	3.65	2.81	3.08	3.41	40.10

RAINFALL AT MEDFORD, MASS. Elevation, 17 feet.

(Medford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1884	4.70	6.24	3.18	4.49	2.14	3.28	3.84	4.60	0.75	2.87	2.61	4.69	43.39
1885	5.53	3.53	0.96	3.39	3.73	3.94	1.92	5.98	1.62	6.04	6.13	2.10	44.87
1886	6.82	7.31	3.73	1.81	2.99	2.93	2.98	2.67	3.17	2.65	3.83	4.74	45.63
1887	6.03	4.67	4.75	3.55	1.57	2.02	4.45	3.67	1.23	3.16	2.96	3.72	41.78
1888	3.80	3.25	4.53	2.82	4.96	2.21	2.26	6.72	7.79	4.73	6.30	4.94	54.31
1889	5.47	1.71	1.60	4.12	4.46	3.51	8.46	4.06	4.90	4.31	6.22	2.20	51.02
1890	2.51	3.35	6.13	2.48	5.71	3.53	2.07	3.64	3.49	8.92	1.36	4.14	47.33
1891	6.32	4.44	5.35	2.37	2.46	4.20	3.14	3.45	3.06	3.40	2.33	2.43	42.95
1892	4.68	2.53	3.06	0.84	5.58	3.33	1.59	6.34	1.89	1.94	4.62	1.34	37.74
1893	2.00	5.63	1.72	3.51	6.42	2.15	1.55	5.32	2.01	4.11	2.15	4.89	41.46
1894	3.07	3.01	0.95	...	...	...	...	...	...	...	...	...	....
Av. 10 yrs.	4.79	4.27	3.50	2.94	4.00	3.11	3.23	4.64	2.99	4.21	3.85	3.52	45.05

RAINFALL AT MIDDLEBOROUGH, MASS. Elevation, 53 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.29	2.71	3.88	3.94	2.31	0.91	3.40	3.11	1.50	2.22	3.51	5.02	35.80
1915	8.57	4.12	0.06	2.60	1.49	1.85	3.56	5.73	1.43	3.14	1.88	4.91	39.34
1916	1.57	4.51	2.68	4.60	4.15	4.71	8.71	1.41	1.49	2.55	3.13	3.06	42.57
1917	2.90	2.84	5.12	3.54	5.38	5.38	1.65	3.29	2.57	5.57	0.30	2.26	40.80
1918	3.22	3.04	2.05	4.56	1.35	2.80	6.36	2.12	3.66	0.77	2.16	3.35	35.44
1919	4.83	3.38	4.55	3.25	4.07	1.72	5.44	7.08	5.17	1.97	3.95	2.29	47.70
1920	3.04	5.61	4.40	4.81	4.69	6.67	2.47	2.48	2.86	1.87	3.57	3.37	45.84
Av. 33 yrs.	4.07	4.02	4.17	3.65	3.36	2.92	3.26	3.26	3.50	4.01	3.62	3.79	43.63

RAINFALL AT MILFORD, MASS. Elevation, 275 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	4.79	3.48	0.00	1.17	2.12	0.93	8.69	5.00	0.91	2.56	2.60	5.51	37.76
1916	1.42	4.88	3.88	3.55	3.11	4.76	5.77	1.80	1.45	1.37	2.36	2.75	37.10
1917	3.67	2.41	4.10	1.71	5.09	3.99	1.07	5.98	2.62	6.32	1.15	2.40	40.51
1918	3.47	3.86	2.83	4.45	1.28	3.00	3.66	2.14	8.78	0.87	2.66	2.65	39.65
1919	3.91	2.86	5.10	3.18	4.02	1.33	4.03	4.18	5.69	2.41	4.15	1.94	42.80
1920	2.36	4.92	4.22	4.74	3.36	5.74	2.67	2.15	2.12	1.17	5.10	4.03	42.58
Av. 6 yrs.	3.27	3.74	3.36	3.13	3.16	3.29	4.32	3.54	3.60	2.45	3.00	3.21	40.07

RAINFALL AT MILTON, MASS. Elevation, 100 feet.

(Rev. A. K. Teele.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1885	...	...	...	...	3.91	3.14	1.53	5.89	1.73	6.10	6.18	2.06	....
1886	5.17	7.70	1.83	3.56	3.95	1.56	2.16	3.64	2.89	3.89	3.22	4.92	44.49
1887	4.48	4.80	5.20	3.78	2.39	2.26	4.81	3.83	1.66	2.73	2.41	3.72	42.07
1888	3.13	2.66	6.23	1.86	4.12	1.59	1.25	6.32	8.70	4.69	9.66	5.18	55.39
1889	6.58	2.06	2.73	3.95	3.90	4.81	9.30	3.42	4.87	4.87	4.94	2.36	53.79
1890	2.45	3.60	8.39	3.34	5.31	1.94	1.41	3.11	7.01	8.22	1.24	5.48	51.50
1891	6.56	5.34	4.58	2.31	2.03	3.74	3.39	4.31	3.14	6.30	2.88	4.00	48.58
1892	4.69	3.75	3.32	0.73	5.02	2.86	1.82	4.66	1.95	2.45	5.29	1.03	37.57
1893	2.35	5.32	2.50	1.92	4.53	2.80	2.06	6.69	1.45	2.29	1.98	3.77	37.66
1894	2.13	3.72	0 93	3.20	3.39	1.35	2.63	1.21	2.46	6.02	3.68	4.48	35.20
1895	3.95	1.08	2.54	4.25	2.15	1.51	3.48	3.11	2.35	9.94	5.66	2.55	42.57
1896	2.33	4.29	...	...	...	...	...	...	...	...	...	...	....
Av. 10 yrs.	4.15	4.00	3.83	2.89	3.68	2.44	3.23	4.03	3.65	5.14	4.10	3.74	44.88

RAINFALL AT MILTON, MASS. Elevation, 640 feet.

(Blue Hill Observatory.)*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.30	3.52	4.20	5.51	2.95	1.75	3.38	4.59	0.45	2.03	3.06	4.56	40.30
1915	7.38	4.30	0.06	2.44	2.01	1.13	9.52	4.83	0.74	3.11	2.47	5.69	43.98
1916	1.84	5.37	4.16	5.43	3.97	5.31	7.55	2.81	1.66	1.81	1.88	3.71	45.50
1917	3.32	3.15	5.03	3.18	5.86	4.77	0.85	8.58	3.17	6.88	0.63	3.36	48.78
1918	3.34	3.05	3.68	4.19	3.21	2.54	6.10	1.63	9.36	1.15	2.19	4.42	44.86
1919	4.20	3.59	5.52	3.17	5.62	2.56	5.51	7.39	7.28	3.14	5.81	2.45	56.24
1920	3.28	7.43	5.32	6.43	7.55	8.64	3.04	5.31	2.99	2.23	6.81	4.78	63.81
Av. 35 yrs.	4.09	4.00	4.33	3.69	3.59	3.16	3.90	3.95	4.08	3.91	3.81	3.88	46.39

* For gage at Valley Station, see Boston.

RAINFALL AT MONROE BRIDGE, MONROE, MASS. Elevation, 840 feet.

(Power Construction Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	**2.80**	**2.24**	**4.60**	5.36	1.15	1.70	4.12	5.85	1.15	1.83	2.38	3.11	36.29
1915	4.64	4.89	0.13	1.62	1.63	2.57	11.30	7.07	3.45	3.27	2.46	4.08	47.11
1916	2.89	4.75	3.36	3.73	4.55	4.65	4.70	2.89	4.79	1.81	4.80	2.41	45.33
1917	4.18	3.03	4.09	2.39	3.89	5.35	2.28	4.90	1.14	6.91	1.03	2.82	42.01
1918	2.61	3.34	3.31	2.10	4.43	3.28	1.96	1.79	6.31	2.35	2.66	4.01	38.15
1919	2.47	2.69	5.26	2.11	8.32	2.08	3.00	4.91	7.45	3.90	5.12	2.10	49.41
1920	1.90	2.95	3.41	5.94	2.06	5.68	4.19	4.72	4.02	4.48	5.80	6.03	51.18
Av. 7 yrs.	3.07	3.41	3.45	3.32	3.72	3.62	4.51	4.59	4.04	3.51	3.46	3.51	44.21

RAINFALL AT MONSON, MASS. Elevation, 370 feet.

(Dr. G. E. Fuller.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1885	4.25	3.50	1.62	2.96	2.25	1.79	2.33	8.68	0.89	3.49	5.31	3.39	40.46
1886	4.63	5.69	3.55	1.95	3.17	2.10	3.54	4.90	2.58	3.14	5.18	4.64	45.07
1887	5.70	4.37	4.56	3.15	0.79	4.11	6.27	7.98	1.48	2.33	3.19	3.92	47.85
1888	3.58	4.49	7.01	2.16	3.69	4.01	4.07	4.00	7.44	4.95	5.25	6.21	56.86
1889	3.94	4.13	4.02	2.87	1.95	3.16	8.12	2.76	2.72	6.21	5.51	3.31	48.70
1890	3.34	3.43	6.60	2.66	5.86	2.23	5.16	4.61	3.54	5.81	0.89	3.53	47.66
1891	7.33	5.38	3.01	3.07	1.86	2.84	4.88	3.27	3.40	4.18	2.36	4.20	45.78
1892	5.15	1.57	2.55	0.44	5.87	3.56	5.26	5.69	2.58	1.08	5.22	1.32	40.29
1893	2.71	7.45	3.31	3.60	5.51	3.68	2.09	3.24	3.39	5.33	1.14	4.79	46.24
1894	3.12	3.03	1.75	2.57	2.87	1.53	1.81	1.57	2.78	3.81	4.17	2.60	31.61
1895	2.66	0.95	1.97	4.22	2.46	4.24	4.20	3.45	5.51	7.25	4.87	4.25	46.03
1896	1.79	6.14	5.32	1.75	2.90	3.10	4.85	2.03	6.20	4.01	2.38	1.63	42.10
1897	4.18	3.07	3.46	1.61	5.15	3.96	9.45	3.23	1.31	1.07	7.21	5.70	49.40
1898	5.26	3.93	2.85	3.94	3.66	3.33	6.14	10.00	3.30	5.97	7.25	3.06	58.69
1899	3.64	4.11	6.51	1.25	1.58	4.54	5.92	4.47	3.29	1.81	2.57	2.52	42.21
1900	4.51	7.58	5.88	2.36	4.90	5.18	4.53	3.54	2.08	4.01	6.30	2.83	53.70
1901	1.88	1.10	5.96	6.69	7.19	1.26	3.50	5.82	4.54	3.53	2.36	10.06	53.89
1902	2.30	3.26	5.46	3.52	2.61	4.69	5.59	4.30	4.43	5.08	0.93	7.20	49.37
1903	2.38	3.94	6.73	3.21	1.07	5.88	2.44	4.14	3.49	3.15	2.76	4.14	43.33
1904	3.95	3.46	3.72	5.67	2.34	2.49	3.85	4.72	6.80	1.97	1.86	2.70	43.53
1905	4.32	1.59	4.56	2.56	1.16	6.00	1.88	4.92	7.01	1.99	2.19	3.42	41.60
1906	2.91	2.27	5.05	2.87	5.14	3.12	8.04	2.16	2.25	5.47	2.19	3.80	45.27
1907	2.80	2.11	1.61	3.05	4.11	2.38	2.65	1.30	9.79	6.67	5.72	4.83	47.02
1908	3.55	4.44	3.62	2.31	4.96	2.55	2.34	5.56	1.50	1.73	1 10	3.00	36.66
1909	3.44	5.23	4.08	5.74	**3.57**	**1.45**	**1.38**	**4.58**	**4.74**	**1.46**	**2.34**	2.35	40.36
1910	5.62	4.66	1.44	2.85	2.51	3.15	2.62	4.00	2.51	1.05	3.97	2.39	36.77
1911	3.15	2.45	3.85	2.55	0.59	**2.81**	**3.97**	7.62	4.47	3.71	4.16	**2.81**	42.14
Av. 27 yrs.	3.78	3.83	4.08	3.02	3.32	3.30	4.33	4.54	3.85	3.71	3.65	3.87	45.28

RAINFALL AT MONTAGUE, MASS. Elevation, 200 feet.

(Turners Falls Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.29	2.09	2.66	5.12	2.81	1.74	4.71	2.43	0.40	2.00	1.57	2.66	31.48
1915	5.16	4.65	0.22	2.75	1.67	2.24	8.84	10.06	1.63	2.98	3.00	6.34	49.54
1916	2.38	5.40	2.98	4.08	3.22	6.04	4.74	4.19	2.98	1.41	2.91	3.46	43.79
1917	2.94	2.35	2.98	1.87	4.79	6.23	2.39	3.46	0.95	6.83	0.73	3.19	38.71
1918	4.00	2.23	3.46	3.12	3.43	3.84	1.51	1.96	5.01	1.44	2.22	3.27	35.49
1919	2.25	2.58	5.37	1.82	5.85	0.96	3.08	3.44	3.29	2.39	5.72	1.83	38.58
1920	2.46	4.88	3.15	6.18	2.72	6.26	2.41	4.50	5.11	1.16	5.20	6.13	50.16
Av. 29 yrs.	3.19	2.87	3.54	2.94	3.22	3.25	3.58	4.02	3.51	2.92	3.02	3.33	39.39

RAINFALL AT NANTUCKET, MASS. Elevation, 15 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.68	4.00	4.63	3.30	3.38	2.58	3.25	4.42	1.61	2.15	2.32	6.73	41.05
1915	6.34	3.32	0.25	1.72	4.01	1.31	1.32	4.93	0.85	3.18	2.13	3.87	33.23
1916	2.03	4.04	3.60	2.90	4.35	4.89	5.02	1.05	1.44	1.92	2.55	3.24	37.03
1917	2.68	2.96	5.85	4.21	4.22	7.69	3.32	1.56	2.37	4.59	0.62	2.13	42.20
1918	2.71	2.22	2.42	3.84	1.44	3.19	1.47	1.62	2.06	2.12	1.53	3.65	28.27
1919	4.83	1.86	3.81	2.46	4.67	2.82	4.76	7.17	3.45	4.25	4.20	3.67	47.95
1920	3.84	7.00	3.46	3.86	4.15	3.58	1.98	4.43	1.18	3.96	3.32	4.24	45.00
Av. 46 yrs.	3.84	3.19	3.67	3.34	3.19	2.76	2.64	3.19	2.79	3.58	3.31	3.98	39.48

RAINFALL AT NEW BEDFORD, MASS. Elevation, 100 feet.

(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1903	4.00	3.75	7.31	5.27	0.69	3.29	1.92	3.78	1.58	2.96	2.54	2.48	39.57
1904	4.19	3.71	1.45	8.19	3.20	4.79	2.00	5.40	2.61	0.99	1.48	3.95	41.96
1905	3.13	1.37	2.36	1.71	1.52	6.29	2.10	3.96	5.63	1.89	2.89	3.75	36.60
1906	3.66	4.21	5.53	2.59	3.51	3.48	4.73	2.26	5.14	3.12	3.16	1.75	43.14
1910	5.56	4.70	1.68	1.71	2.81	3.07	2.47	2.01	1 53	2.05	3.75	3.04	34.38
1911	3.73	2.81	3.44	4.51	1.45	1.84	5.75	6.57	2.93	2.47	6.21	3.78	45.49
1912	5.90	3.20	7.72	3.02	3.59	0.15	1.49	7.35	2.19	0.96	3.95	6.93	46.45
1913	5.87	3.87	4.71	4.57	1.62	0.63	1.87	4.68	3.48	7.40	2.37	4.14	45.21
1914	3.57	4.84	3.37	3.76	2.62	0.90	4.53	3.17	0.66	3.07	3.55	5.38	39.42
1915	10.09	4.07	0.10	2.17	2.49	2.50	2.76	6.05	1.37	4 67	1.68	4.04	41.99
1916	1.63	3.85	2.89	3.76	5.53	4.70	9.39	2.10	1.68	3.37	3.24	2.81	44.95
1917	3.51	2.25	5.05	3.23	5.14	5.80	0.93	3.00	3.37	3.92	0.32	1.82	38.34
1918	3.10	2.33	1.93	3.12	1.51	3.93	2.09	2.58	2.68	0.47	2.05	3.64	29.43
1919	3.44	3.75	3.15	2.83	3.91	3.22	6.83	5.70	4.74	2.13	3.28	2.46	45.44
1920	2.03	4.97	4.03	5.79	5.13	6.17	1.43	2.13	0.90	1.62	3.92	3.02	41.14
Av. 15 yrs.	4.23	3.58	3.65	3.75	2.98	3.38	3.35	4.05	2.70	2.74	2.97	3.52	40.90

RAINFALL AT NEW BEDFORD, MASS. Elevation, 100 feet.

(L. J. Hathaway, Jr.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.64	3.37	3.80	4.31	2.80	0.93	5.17	2.87	0.85	2.51	2.90	5.55	38.70
1915	10.75	4.57	0.09	2.92	1.81	1.55	2.50	6.94	1.81	4.40	1.79	4.70	43.83
1916	1.78	4.21	3.27	3.84	5.04	4.65	11.20	1.33	1.30	3.47	3.12	3.15	46.36
1917	3.08	2.79	5.87	3.44	4.85	4.86	0.89	3.39	2.56	4.47	0.35	2.09	38.64
1918	3.42	3.22	2.02	4.01	1.67	3.15	2.79	1.99	3.84	0.77	2.46	3.56	32.90
1919	5.11	3.66	3.41	3.08	4.21	2.22	5.27	6.81	4.47	2.35	3.94	2.78	47.31
1920	3.12	6.61	5.09	5.70	4.94	7.55	1.51	3.15	2.20	1.59	4.09	4.22	49.77
Av. 107 yrs.	4.03	3.89	4.27	3.94	3.94	3.12	3.30	4.15	3.45	3.86	4.14	4.12	46.21

RAINFALL AT NEWBURYPORT, MASS. Elevation, 80 feet.
(Plum Island Coast Guard Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	2.12	2.55	4.31	4.58	3.50	0.67	0.91	2.71	1.78	6.43	1.65	3.18	34.39
1914	2.55	2.07	3.66	6.23	2.47	1.54	3.58	3.62	0.29	1.29	2.61	2.34	32.25
1915	4.82	2.87	0.06	2.19	1.48	1.75	10.35	6.04	0.45	3.20	1.95	3.99	39 15
1916	0.91	3.39	1.65	4.32	3.21	7.35	4.35	1.99	2.24	0.92	2.26	1.84	34.43
1917	2.59	1.36	3.12	2.80	2.87	6.04	0.93	4.16	1.14	5.75	1.34	2.48	34.58
1918	2.09	2.78	1.21	3.45	0.96	2.79	3.25	3.26	7.27	1.55	2.78	3.15	34.54
1919	3.46	2.25	2.55	2.21	4.27	3.74	2.66	2.84	5.46	2.88	4.35	1.42	38.09
1920	1.35	7.26	2.62	5.66	3.73	4.66	3.06	1.96	5.24	0.84	5.00	3.35	44.73
Av. 8 yrs.	2.49	3.07	2.40	3.93	2.81	3.57	3.64	3.32	2.98	2.85	2.74	2.72	36.52

RAINFALL AT NEWTON, MASS. Elevation, 100 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.54	2.91	5.14	5.40	2.68	1.95	2.13	3.15	0.24	1.73	2.60	3.67	35.14
1915	6.98	3.28	0.02	3.44	1.46	1.28	9.11	5.69	0.99	2.63	2.68	5.05	42.61
1916	1.50	5.13	3.63	4.64	2.93	4.97	4.60	2.90	1.35	1.30	1.84	2.95	37.74
1917	3.17	2.31	4.36	2.60	5.45	4.31	0.86	7.19	2.44	5.71	1.08	2.24	41.72
1918	2.95	3.86	2.05	4.86	1.45	2.30	3.88	1.77	9.42	1.14	1.85	3.36	38.89
1919	3.69	3.28	4.51	2.93	5.47	1.53	5.84	5.12	7.63	2.33	5.30	1.79	49.42
1920	3.24	6.33	3.75	5.27	3.87	6.59	1.95	2.11	2.81	1.16	5.88	4.43	47.39
Av. 13 yrs.	3.55	3.73	3.50	3.72	3.07	2.81	3.55	3.72	3.15	2.54	3.06	3.32	39.72

RAINFALL AT NORFOLK, MASS. Elevation, 244 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.32	3.46	4.45	5.34	3.04	0.90	3.85	4.36	0.43	1.79	3.18	3.83	37.95
1915	7.10	3.12	T	1.96	1.63	1.51	9.77	5.22	0.46	2.63	2.42	**5.34**	41.16
1916	1.35	4.37	3.17	3.73	3.71	6.90	5.96	2.12	1.73	2.00	1.94	3.18	40.16
1917	3.11	2.22	4.91	2.90	5.54	4.71	1.47	8.33	2.99	6.12	0.42	2.15	44.87
1918	3.74	2.80	3.19	4.25	3.16	3.07	3.90	1.51	10.56	0.81	1.76	**2.23**	40.98
1919	3.41	3.47	5.14	3.07	4.83	2.57	6.02	5.29	7.05	2.41	5.30	2.31	50.87
1920	**2.84**	**5.11**	**4.06**	6.26	3.99	5.80	3.13	2.90	2.54	1.18	4.99	6.09	48.89
Av. 18 yrs.	3.55	3.14	3.37	3.57	3.12	3.18	3.78	3.75	3.93	3.22	2.93	3.46	41.00

RAINFALL AT NORTH ADAMS, MASS. Elevation, 1 200 feet.
(Notch Brook Reservoir.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.90	4.13	4.61	6.04	1.71	2.31	3.59	4.16	0.39	1.06	2.01	2.42	35.33
1915	3.99	4.44	0.55	2.36	1.53	2.01	8.05	4.75	2.49	2.41	2.03	6.15	40.76
1916	1.85	4.11	4.93	3.49	3.08	3.25	4.28	2.60	4.20	1.81	4.71	3.15	41.46
1917	3.18	2.49	2.99	1.49	2.63	3.17	2.37	3.77	0.97	5.19	0.87	2.61	31.73
1918	2.55	2.89	1.41	2.28	4.15	2.66	1.67	1.85	5.16	2.71	2.18	3.77	33.28
1919	2.87	1.13	4.03	1.65	6.31	1.98	2.98	5.15	5.74	3.03	4.05	2.04	40.96
1920	2.44	4.60	5.08	4.78	1.18	3.94	5.16	2.87	6.05	2.11	5.95	4.04	48.20
Av. 21 yrs.	2.98	3.20	3.51	3.15	3.02	3.34	3.71	3.89	3.48	3.16	2.61	3.37	39.42

RAINFALL AT NORTH ADAMS, MASS. Elevation, 1 000 feet.
(Broad Brook Reservoir.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.50	1.80	4.45	6.06	1.63	2.37	4.08	3.85	0.48	1.33	2.28	1.81	32.64
1915	4.04	5.29	0.27	2.73	1.60	1.50	9.10	4.57	4.17	2.46	1.79	8.12	45.64
1916	2.22	2.79	3.60	1.84	2 84	3.56	4.24	2.27	5.59	1.51	4.62	3.07	38.15
1917	2.43	1.80	3.27	1.26	2.40	3.45	1 77	3.75	1.37	6.21	0.68	2.30	30.69
1918	2.98	1.90	1.66	2.06	2.82	3.24	2.86	2.87	7.10	2.72	1.94	3.40	35.55
1919	2.47	1.83	6.12	1.84	6.11	2.20	2.96	6.14	6.41	4.03	5.86	1.81	47.78
1920	1.72	4.63	3.70	5.28	2.22	4.22	3.32	4.96	3.33	5.11	5.43	4.34	48.26
Av. 21 yrs.	2.99	2.67	3.51	3.30	3.21	3.78	4.06	4.41	3.67	3.45	2.80	3.35	41.20

RAINFALL AT NORTHAMPTON, MASS. Elevation, 850 feet.
(Mt. Nonotuck.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1886	5.39	4.05	3.69	3.41	3.27	2.09	4.32	2.10	4.46	3.03	5.27	3.45	44.53
1887	6.36	5.33	4.32	4.23	1.13	5.84	7.28	7.89	1.71	2.20	3.61	5.06	54.96
1888	4.46	4.87	6.98	3.02	4.76	4.61	3.16	4.81	10.18	5.13	4.76	4.70	61.44
1889	...	...	...	2.08	3.84	5.36	9.43	2.32	4.84	3.05	6.92	3.18	....
1890	3.38	4.00	4.56	1.75	4.23	2.63	5.46	5.74	6.21	6.91	1.25	2.57	48.69
1891	7.94	5.63	2.66	3.13	1.97	3.49	5.98	5.65	2.33	2.69	2.50	4.01	47.98
1892	4.69	2.76	2.20	0.75	4.57	2.85	3.80	6.63	1.67	0.56	5.19	1.24	36.91
1893	3.45	6.51	3.72	...	...	...	...	...	...	...	2.13	5.17	....
1894	3.06	2.50	1.48	1.85	3.39	0.25	2.02	0.63	4.12	5.29	3.71	4.08	32.38
1895	3.96	1.35	1.51	3.41	2.08	4.24	5.00	3.64	4.06	4.76	4.08	3.42	41.51
1896	0.76	3.95	7.08	1.43	2.70	3.06	4.62	3.20	6.17	3.41	2.85	1.01	40.24
1897	3.42	2.44	3.42	2.63	4.14	5.73	15.37	3.68	1.62	0.73	5.95	5.63	54.76
1898	6.84	5.30	...	4.04	...	...	...	...	...	...	...	...	....

RAINFALL AT NORTHAMPTON, (MT. TOM), MASS.* Elevation, 200 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1901	...	...	...	11.33	8.89	...	3.01	7.72	4.68	6.55	1.46	7.94	....
1902	2.48	4.87	8.28	5.02	2.72	3.12	4.76	5.64	7.21	6.33	1.40	6.55	58.38
1903	2.99	4.68	6.54	2.53	1.01	11.06	5.71	8.54	2.44	4.05	2.37	5.47	57.39
1904	4.16	2.69	4.87	7.81	6.11	8.84	4.03	4.70	6.87	2.74	1.20	2.99	57.01
1905	6.57	1.56	4.48	3.62	0.96	4.02	3.20	6.44	8.32	2.39	1.35	3.88	46.79
1906	2.01	2.55	6.42	6.03	5.49	5.73	2.22	8.01	3.66	8.27	4.12	4.65	59.16
1907	2.79	2.85	2.64	2.49	4.88	3.42	5.62	1.69	11.22	7.19	5.78	5.14	55.71
1908	3.47	5.36	3.53	2.39	5.54	1.00	3.79	5.00	1.22	2.70	1.10	1.77	36.87
1909	3.80	4.63	3.13	3.20	2.15	2.70	1.57	4.82	5.32	1.78	2.32	3.77	39.19
1910	6.15	4.18	1.67	5.06	2.29	3.87	1.86	3.52	3.36	0.92	3.44	2.09	38.41
1911	2.31	2.18	3.96	...	...	...	...	...	...	9.48	3.12	2.48	....
1912	1.72	2.76	...	...	...	...	...	...	...	...	...	...	....
Av. 9 yrs.	3.82	3.71	4.62	4.24	3.46	4.86	3.64	5.37	5.51	4.04	2.56	4.03	49.86

*Mt. Tom record stops March, 1908; Northampton record starts April, 1908.

RAINFALL AT NORTH ANDOVER, MASS. Elevation, 100 feet.
(Ingalls Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1911	...	...	...	...	0.28	3.13	5.69	4.85	2.08	3.12	4.30	3.92	....
1912	2.74	2.34	4.93	3.60	4.29	0.36	5.03	1.66	2.31	1.70	2.88	4.63	36.47
1913	1.85	2.86	4.15	3.95	3.41	2.01	1.35	3.84	3.47	8.37	2.27	3.03	40.56
1914	2.78	2.62	3.80	6.48	2.73	1.90	2.65	3.00	0.21	1.29	2.51	3.06	33.03
1915	5.07	3.24	0.02	2.24	1.54	1.71	12.41	6.60	0.86	2.82	2.71	4.81	44.03
1916	1.37	4.09	2.20	4.92	4.43	5.85	4.70	1.94	2.35	1.01	2.12	2.54	37.52
1917	3.16	2.15	3.72	2.77	4.18	4.33	3.06	2.72	1.54	6.34	0.86	2.83	37.66
1918	2.54	2.92	1.48	3.66	1.05	3.20	3.57	2.79	7.35	1.09	2.85	2.81	35.31
1919	3.52	3.19	3.46	2.88	5.59	1.36	2.35	3.96	5.30	2.57	6.08	1.43	41.69
1920	1.82	4.18	2.93	6.11	3.60	5.07	1.26	3.27	4.10	1.24	6.31	4.78	44.67
Av. 9 yrs.	2.76	3.07	2.96	4.07	3.42	2.87	4.04	3.31	3.05	2.94	3.18	3.32	38.99

RAINFALL AT NORTH ATTLEBOROUGH, MASS. Elevation, 200 feet.
(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	7.00	3.50	9.10	7.30	3.50	1.40	...	3.95	3.69	9.32	3.87	3.31	....
1914	...	...	...	...	...	...	...	...	...	...	...	...	....
1915	8.14	3.32	0.05	1.54	2.03	6.82	4.25	5.23	0.52	2.11	2.63	4.77	41.41
1916	1.54	4.25	2.33	3.53	4.25	5.28	6.09	1.47	1.05	2.62	1.99	2.81	37.21
1917	3.01	2.00	4.48	2.53	4.86	4.49	1.04	6.70	2.27	6.59	0.36	2.47	40.80
1918	3.29	2.66	2.58	3.93	2.30	3.40	3.54	1.73	9.26	0.79	2.17	3.27	38.92
1919	4.23	3.22	4.93	2.65	5.62	2.09	5.56	5.36	5.20	2.08	4.28	2.15	47.37
1920	2.26	4.93	3.82	4.60	4.76	5.76	3.38	1.32	1.38	1.15	4.60	4.13	42.09
Av. 6 yrs.	3.74	3.40	3.03	3.13	3.97	4.63	3.98	3.64	3.28	2.56	2.67	3.27	41.30

RAINFALL AT NORTHBRIDGE, MASS. Elevation, 350 feet.

(Whitinsville.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.76	2.99	5.09	4.89	2.79	1.61	3.16	4.25	0.28	1.83	2.82	3.64	37.11
1915	7.36	3.58	0.03	2.03	2.34	2.27	8.92	6.18	1.52	3.01	2.63	4.91	44.78
1916	1.61	6.49	3.50	3.94	3.56	5.60	5.14	1.52	2.07	1.67	2.71	2.88	40.69
1917	2.96	3.22	4.19	1.96	4.83	4.70	1.16	8.62	1.59	6.08	0.78	2.71	42.80
1918	3.37	2.82	3.20	3.40	4.11	4.62	3.35	1.58	8.63	1.04	2.77	3.28	42.17
1919	3.90	2.20	5.46	3.54	5.32	1.60	3.43	5.87	6.99	2.88	5.72	2.15	49.06
1920	3.10	5.80	4.76	4.91	3.95	6.67	2.87	1.95	4.55	1.14	5.11	4.83	49.64
Av. 49 yrs.	3.92	3.91	4.33	3.55	3.41	3.19	3.65	4.33	3.45	3.79	3.70	3.69	44.92

RAINFALL AT NORWOOD, MASS. Elevation, 90 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	2.51	3.08	4.82	4.41	2.71	1.69	2.24	4.23	2.53	7.29	2.31	3.02	40.84
1914	2.23	2.88	3.18	4.97	2.78	1.13	3.34	5.25	0.38	1.73	2.68	4.13	34.68
1915	7.09	3.27	0.02	2.04	1.51	1.24	11.46	4.81	0.63	2.81	2.41	5.25	42.54
1916	1.21	4.51	2.40	4.25	3.56	4.80	7.90	2.23	1.61	1.41	1.71	2.91	38.50
1917	3.23	1.83	4.08	2.27	5.80	4.58	0.48	11.40	2.26	6.05	0.78	2.00	44.76
1918	3.05	2.89	2.10	4.54	1.21	2.80	6.41	2.04	8.94	0.87	2.12	3.25	40.22
1919	3.55	2.92	4.72	3.03	5.67	1.77	5.05	4.78	6.65	2.83	4.84	1.73	47.54
1920	2.08	4.97	3.64	5.26	3.88	6.90	2.70	4.38	3.39	1.20	6.02	3.62	48.04
Av. 8 yrs.	3.12	3.30	3.12	3.85	3.39	3.11	4.94	4.89	3.30	3.02	2.86	3.24	42.14

RAINFALL AT OTIS, MASS. Elevation, 1 400 feet.

(West Otis Post Office.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.36	2.21	5.72	4.29	3.71	0.96	2.50	4.01	3.44	8.15	4.19	2.08	44.62
1914	2.40	3.35	4.06	4.70	2.13	2.67	4.26	2.74	0.52	1.72	2.83	2.42	33.80
1915	6.14	4.46	0.30	2.18	2.65	4.79	6.78	7.27	3.02	2.40	2.14	4.56	46.69
1916	1.86	3.86	2.33	3.42	2.62	4.02	6.11	2.78	5.00	1.78	3.94	2.73	40.45
1917	3.28	1.85	3.27	1.27	3.66	4.79	3.17	1.66	1.51	5.60	2.25	1.45	33.76
1918	2.85	3.43	1.59	3.26	2.99	4.16	2.62	5.35	5.64	1.61	2.47	3.29	39.26
1919	2.23	3.02	4.45	2.41	7.28	1.78	4.26	3.24	4.52	3.25	5.31	2.51	44.26
1920	2.15	3.89	2.89	6.24	1.88	6.75	3.69	5.81	6.33	1.48	4.65	5.37	51.13
Av. 8 yrs.	3.03	3.26	3.08	3.47	3.37	3.74	4.17	4.11	3.75	3.25	3.47	3.05	41.75

RAINFALL AT PEABODY, MASS. Elevation, 75 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.49	3.80	3.42	6.67	2.45	1.38	2.31	2.95	0.35	1.48	2.63	3.26	34.19
1915	6.18	4.14	0.01	2.45	1.18	1.81	8.24	7.37	1.05	3.04	2.84	4.24	42.55
1916	1.68	4.36	2.65	4.49	3.99	5.87	2.94	2.71	2.09	0.96	2.18	3.02	36.94
Av. 14 yrs.	3.46	3.20	4.13	3.36	2.92	3.64	3.53	3.23	2.95	2.71	3.15	3.37	39.65

RAINFALL AT PEMBROKE, MASS. Elevation, 65 feet.

(Brockton Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.36	3.73	3.27	3.78	4.09	4.40	7.15	2.30	2.05	2.75	3.02	2.81	40.71
1917	3.42	1.71	4.68	3.65	4.98	4.84	2.21	5.59	2.71	5.50	0.24	2.29	41.82
1918	3.34	2.71	2.67	5.17	1.25	3.02	4.86	1.73	5.76	0.71	1.88	3.44	36.54
1919	4.63	3.28	4.66	3.70	3.64	4.52	5.63	6.87	7.21	2.69	5.14	2.46	54.43
1920	2.89	5.46	4.69	4.57	4.92	7.73	3.40	2.49	3.92	1.79	4.33	3 68	49.87
Av. 5 yrs.	3.13	3.38	3.99	4.18	3.76	4.90	4.65	3.80	4.33	2.69	2.92	2.94	44.67

RAINFALL AT PERU, MASS. Elevation, 1 700 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.58	2.48	6.25	3.12	3.43	0.62	2.09	1.90	3.41	6.49	5.10	1.80	40.27
1914	1.71	3.35	4.79	4.94	2.81	2.32	3.07	5.01	0.44	1.39	2.69	2.66	35.18
1915	5.75	5.24	0.22	2.93	1.72	2.67	10.91	7.11	2.26	2.26	2.33	7.04	50.44
1916	2.44	5.21	3.75	4.06	3.41	3.88	5.00	4.17	5.39	1.43	4.03	3.06	45.83
1917	3.29	2.25	4.18	1.42	1.24	5.92	3.42	2.77	1.40	5.84	0.63	2.88	38.24
1918	3.39	3.40	2.15	3.71	3.55	3.43	1.84	3.03	6.47	2.10	2.53	3.48	39.08
1919	2.62	2.73	4.25	2.34	7.29	1.57	7.08	4.30	5.82	3.84	5.49	2.12	49.45
1920	2.41	6.39	4.69	5.60	1.92	5.53	2.47	4.26	7.37	1.57	6.52	4.76	53.49
Av. 8 yrs.	3.15	3.88	3.79	3.51	3.55	3.24	4.49	4.07	4.07	3.11	3.66	3.48	44.00

RAINFALL AT PETERSHAM, MASS. Elevation, 1 100 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.36	2.35	2.65	3.09	3.28	4.73	6.95	4.41	7.24	1.23	3.93	3.20	44.42
1917	2.84	3.64	4.35	1.75	4.49	5.39	1.80	5.22	0.78	5.84	1.25	1.51	38.86
1918	3.35	3.18	2.04	3.30	2.11	4.87	2.14	2.60	7.50	0.99	2.67	4.05	38.80
1919	3.05	2.82	5.17	2.09	5.96	1.92	5.22	4.80	5.14	3.68	6.62	1.79	48.26
1920	3.11	7.44	2.36	4.79	2.89	4.23	3.30	5.80	5.14	1.51	4.90	6.35	51.82
Av. 5 yrs.	2.74	3.89	3.31	3.00	3.75	4.23	3.88	4.57	5.16	2.65	3.87	3.38	44.43

RAINFALL AT PITTSFIELD, MASS. Elevation 1 050 feet.

(City Hall.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.77	2.51	3.53	6.07	2.74	2.28	4.45	4.26	0.50	1.33	1.76	1.96	33.16
1915	3.48	5.63	0.25	1.13	1.36	2.52	9.07	5.64	2.35	2.39	1.58	7.82	43.22
1916	2.67	3.27	3.89	3.07	2.47	3.51	5.05	1.76	5.80	1.10	4.63	3.80	41.02
1917	3.30	2.48	3.65	1.60	2.85	4.19	4.27	2.78	0.98	5.91	0.45	2.27	34.73
1918	3.22	2.75	3.12	2.89	4.35	3.24	2.00	2.65	7.10	2.78	2.45	3.56	40.11
1919	2.93	2.12	5.60	2.57	6.91	1.60	5.11	3.47	4.60	3.65	5.03	1.45	45.04
1920	1.77	4.45	3.63	3.06	1.18	4.75	2.85	3.89	4.41	4.50	4.23	5.48	44.20
Av. 26 yrs.	2.92	3.00	3.74	2.98	3.13	3.72	4.31	4.18	3.81	3.29	2.89	3.42	41.39

RAINFALL AT PITTSFIELD, MASS. Elevation, 1 600 feet.

(Farnham Reservoir.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	2.93	2.45	3.99	2.06	3.15	4.81	3.00	2.03	0.70	6.42	0.55	2.73	34.82
1918	3.14	1.72	3.20	2.86	3.97	2.91	2.01	2.54	6.37	1.85	2.80	3.27	36.64
1919	2.32	2.09	4.65	1.25	5.25	1.19	4.86	2.67	3.48	2.81	5.05	2.14	37.76
1920	2.25	5.73	4.13	2.66	0.71	3.31	1.92	4.03	3.42	2.87	4.55	3.73	39.31
Av. 4 yrs.	2.66	3.00	3.99	2.21	3.27	3.05	2.95	2.82	3.49	3.48	3.24	2.97	37.13

RAINFALL AT PLYMOUTH, MASS. Elevation, 70 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.62	4.82	5.42	5.45	2.90	1.00	4.62	3.40	1.67	2.20	3.47	6.73	45.30
1915	10.35	3.98	0.09	3.47	2.20	3.88	3.42	6.19	1.55	4.22	2.37	4.99	46.71
1916	1.46	5.51	4.87	5.62	3.51	5.53	9.07	2.19	2.46	2.88	3.40	3.88	50.38
1917	3.36	2.59	6.27	4.88	7.02	6.53	2.20	3.40	3.32	5.02	0.60	2.32	47.51
1918	4.59	2.95	2.52	6.22	0.53	2.95	2.64	1.61	3.68	0.71	2.25	3.79	34.44
1919	5.39	3.77	5.06	3.78	5.47	2.07	4.73	7.65	4.95	2.67	5.58	2.61	53.73
1920	4.24	9.02	5.60	4.92	4.48	7.39	3.04	3.13	2.73	1.84	5.11	4.19	55.69
Av. 34 yrs.	4.38	4.23	4.59	4.30	3.45	3.05	3.30	3.55	3.44	4.13	4.09	4.12	46.63

RAINFALL AT PRESCOTT, MASS. Elevation, 1 000 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.48	4.20	2.74	2.92	2.64	5.82	6.31	3.31	5.23	1.35	3.89	2.27	42.16
1917	3.93	2.48	4.18	1.07	3.76	4.19	1.58	3.40	1.35	5.69	2.07	**1.52**	35.22
1918	2.86	3.53	1.86	2.25	0.94	4.93	0.92	2.80	6.14	1.39	3.11	3.84	34.57
1919	2.25	2.52	5.53	3.12	5.88	1.90	5.32	4.94	6.04	2.52	5.40	1.09	46.51
1920	1.90	3.19	2.47	6.31	3.45	6.94	4.27	5.21	7.56	1.03	3.94	6.45	52.72
Av. 5 yrs.	2.48	3.19	3.36	3.14	3.33	4.76	3.68	3.93	5.26	2.40	3.68	3.03	42.24

RAINFALL AT PRINCETON, MASS. Elevation, 1 125 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.13	3.40	3.46	4.80	2.52	2.02	4.58	3.99	0.11	1.58	3.24	3.68	36.51
1915	5.63	2.51	0.07	1.93	1.61	2.73	8.75	7.25	1.79	2.98	3.30	4.31	42.86
1916	1.54	5.75	2.44	3.14	3.72	6.85	5.93	1.74	4.14	1.47	3.07	2.57	42.36
1917	3.15	2.68	3.28	1.89	3.68	4.33	0.84	3.31	1.22	6.18	1.15	1.09	32.80
1918	2.42	3.27	1.66	3.33	1.16	4.33	2.29	2.75	6.39	1.46	2.82	3.54	35.42
1919	3.16	2.49	5.18	2.43	5.99	1.00	4.22	4.27	6.14	2.34	5.42	1.85	44.49
1920	2.75	5.90	3.92	6.14	3.54	4.92	5.10	4.21	6.02	0.62	5.00	5.37	53.49
Av. 31 yrs.	3.89	3.56	3.93	3.48	3.49	3.42	4.34	4.41	3.72	3.64	3.66	3.76	45.30

RAINFALL AT PROVINCETOWN, MASS. Elevation, 40 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.46	4.44	4.55	2.85	2.68	0.55	3.40	3.64	0.86	1.46	2.07	5.71	35.67
1915	7.19	3.62	T	2.37	2.80	1.56	4.95	3.18	1.16	4.98	2.50	3.12	37.43
1916	1.30	2.91	2.88	3.70	2.42	4.50	8.65	1.41	2.62	2.57	1.05	4.10	38.11
1917	2.60	3.28	4.11	4.37	4.48	7.72	1.33	3.29	2.11	3.82	0.45	2.19	39.75
1918	3.01	3.22	3.17	3.17	1.44	2.94	1.93	2.28	3.59	0.94	1.65	3.10	30.44
1919	4.15	3.40	2.45	3.25	4.15	1.00	4.45	3.95	3.38	2.73	3.25	2.31	38.47
1920	2.40	5.50	4.85	4.75	4.00	4.21	2.15	1.75	1.40	3.05	4.45	4.10	42.61
Av. 27 yrs.	4.02	3.45	3.54	3.30	3.10	2.50	2.70	2.96	2.86	3.58	3.08	3.65	38.74

RAINFALL AT QUINCY, MASS. Elevation, 20 feet.

(Wollaston.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	1.55	1.94	5.07	5.31	2.64	1.48	2.21	3.02	2.79	6.88	2.63	3.09	38.61
1914	3.69	3.98	3.21	5.12	2.91	1.87	3.16	3.99	0.28	1.68	3.31	4.21	37.41
1915	6.84	3.01	T	2.42	1.44	1.32	7.92	5.15	0.91	2.38	2.41	4.68	38.48
1916	1.35	4.91	3.70	4.39	3.24	5.58	5.99	2.20	1.17	1.47	1.85	3.10	38.95
1917	3.00	2.38	4.51	2.56	4.98	5.35	1.77	8.32	2.03	5.66	1.08	2.61	44.25
1918	3.15	2.92	2.55	5.05	1.30	2.01	4.19	1.97	8.17	0.88	1.86	3.30	37.35
1919	3.53	3.05	4.64	2.96	4.26	2.22	4.56	5.88	6.46	2.67	5.06	1.22	46.51
1920	3.25	6.55	4.49	4.69	5.11	5.89	2.24	3.26	3.86	1.12	4.85	3.45	48.76
Av. 8 yrs.	3.30	3.59	3.52	4.06	3.23	3.22	4.01	4.22	3.21	2.84	2.88	3.21	41.29

RAINFALL AT READING, MASS. Elevation, 80 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.34	3.65	4.09	6.32	2.76	1.44	2.34	2.78	0.23	1.51	2.92	3.69	35.07
1915	5.52	3.54	T	2.72	1.68	1.70	11.66	6.66	0.70	2.80	2.93	5.47	45.38
1916	1.22	5.37	3.37	5.14	4.59	5.86	3.13	2.30	3.11	1.01	1.94	2.91	39.95
1917	2.92	2.41	4.18	2.90	4.00	4.78	1.19	3.40	1.46	5.76	1.39	2.66	37.05
1918	2.92	3.02	2.02	4.10	0.85	3.04	2.99	2.81	8.37	1.02	2.24	2.06	35.44
1919	3.68	3.61	4.01	2.46	5.44	0.88	3.22	3.83	5.65	2.63	6.20	1.53	43.14
1920	2.75	6.46	4.18	5.75	3.27	5.27	1.94	2.02	4.27	1.16	5.30	4.77	47.14
Av. 22 yrs.	3.38	3.61	3.85	4.14	3.08	3.21	3.48	3.20	3.70	2.68	3.15	3.44	40.92

RAINFALL AT ROCHESTER, MASS. Elevation, 60 feet.

(Little Quittacas Pond, New Bedford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.42	3.86	3.68	4.43	2.65	0.95	4.80	2.60	1.00	2.51	3.31	4.97	38.18
1915	10.07	3.92	0.18	2.51	2.49	1.64	5.69	7.38	2.11	3.95	1.98	4.52	46.44
1916	1.95	4.21	3.57	4.27	4.66	4.85	11.12	1.25	1.52	3.09	3.21	3.09	46.79
1917	3.19	1.97	5.92	4.69	5.05	5.35	1.72	3.57	2.75	4.97	0.15	2.07	41.40
1918	3.38	4.50	1.65	5.01	1.87	3.40	3.30	2.06	3.85	0.73	2.40	3.70	35.85
1919	5.48	3.91	4.97	3.37	4.27	2.42	5.59	7.94	6.06	1.78	4.23	2.48	52.50
1920	3.40	2.28	5.62	5.28	5.24	8.12	1.88	2.55	1.93	2.90	3.93	3.82	46.95
Av. 22 yrs.	3.96	4.08	4.49	4.15	3.46	3.33	3.34	3.29	3.26	3.56	3.19	4.14	44.25

RAINFALL AT ROCKPORT, MASS. Elevation, 30 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.30	2.13	3.85	5.00	2.46	1.68	1.80	2.09	0.25	1.43	4.10	3.68	31.77
1915	5.74	2.71	0.00	2.56	1.66	1.35	8.13	4.50	1.42	3.35	4.03	4.28	39.73
1916	1.13	2.78	2.43	5.94	2.61	7.08	4.22	2.74	2.30	1.11	1.47	3.94	37.75
1917	2.45	2.00	2.36	3.31	4.59	7.24	1.00	4.68	1.48	4.72	1.14	3.66	38.63
1918	2.53	1.38	1.40	4.36	0.75	2.32	1.92	2.35	10.65	1.16	2.48	3.24	34.54
1919	3.35	3.33	3.92	2.34	3.63	2.10	1.84	4.74	5.71	2.81	6.44	1.93	42.14
1920	1.26	2.51	2.67	5.85	3.85	5.64	0.99	0.92	3.77	1.62	4.77	3.67	37.52
Av. 18 yrs.	3.47	2.96	3.28	3.83	2.66	3.41	3.32	2.64	3.65	2.58	3.17	3.65	38.62

RAINFALL AT RUTLAND, MASS. Elevation, 1 160 feet.

(State Sanatorium.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1902	...	...	...	...	1.57	2.21	3.20	5.62	4.66	8.67	0.62	5.62	....
1903	2.60	3.71	8.31	3.32	1.35	8.78	3.36	4.06	2.87	3.98	2.80	2.05	47.19
1904	1.62	1.65	2.70	7.40	4.48	3.94	4.81	3.31	5.62	1.73	1.07	2.50	40.83
1905	5.02	1.08	3.73	2.53	0.75	5.05	5.00	2.77	5.87	1.85	2.70	4.16	40.51
1906	2.56	2.50	4.15	3.19	6.86	4.78	6.07	5.67	2.34	4.01	2.31	4.25	48.69
1907	2.31	1.42	1.67	2.86	3.51	4.79	3.07	1.44	9.43	6.62	6.79	3.11	47.02
1908	3.10	3.60	1.54	2.47	6.20	1.48	3.94	6.66	1.22	2.54	1.14	3.32	37.21
1909	3.28	6.37	5.05	6.51	2.28	3.21	5.18	4.11	3.59	1.73	2.16	3.90	47.37
1910	5.53	5.66	0.81	2.96	2.05	4.99	1.60	4.23	3.52	1.23	3.86	2.53	38.97
1911	2.99	2.36	3.83	2.47	1.87	2.65	2.62	6.19	3.07	5.42	4.06	3.14	40.67
1912	2.51	2.37	4.85	4.44	5.86	0.36	2.74	3.33	2.76	2.20	4.32	4.95	40.69
1913	3.38	2.45	5.68	4.12	3.93	1.98	2.31	2.51	7.32	6.76	2.73	2.23	45.40
1914	7.38	3.65	5.75	4.93	3.38	2.11	3.29	4.97	0.13	1.73	3.03	4.25	44.60
1915	6.96	3.60	0.09	1.85	1.84	3.98	6.89	6.54	1.77	2.92	3.50	5.05	44.99
1916	1.81	6.38	3.32	3.67	3.33	5.26	8.46	1.84	4.08	1.36	2.67	3.25	45.43
1917	3.48	4.10	4.59	1.99	4.13	4.46	1.53	6.16	1.51	7.01	1.71	2.13	42.80
1918	3.24	4.66	2.21	2.90	1.05	4.63	2.12	3.85	6.81	1.83	3.40	1.13	37.83
1919	3.48	3.54	5.87	2.46	6.66	1.31	4.84	4.62	8.58	2.42	3.58	1.92	49.28
1920	2.88	4.95	4.64	6.50	3.11	6.09	7.72	3.48	6.39	0.81	5.43	5.55	57.55
Av. 18 yrs.	3.56	3.56	3.82	3.70	3.48	3.88	4.20	4.21	4.27	3.12	3.18	3.30	44.28

RAINFALL AT SALEM, MASS. Elevation, 46 feet.

(A. A. Smith.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1886	5.18	7.83	3.66	2.36	3.65	1.57	4.46	3.03	2.81	3.00	3.85	5.64	47.04
1887	5.65	4.50	5.45	4.47	1.64	2.18	3.70	5.68	0.79	2.82	3.16	3.69	43.73
1888	3.70	2.70	5.17	3.23	5.10	1.73	1.96	5.89	7.97	4.94	6.63	5.50	54.52
1889	5.23	2.07	1.66	3.60	3.11	3.89	6.77	4.29	2.80	3.84	6.15	2.82	46.23
1890	2.44	3.21	6.97	2.41	5.65	4.31	2.36	3.56	4.42	7.35	1.51	5.62	49.81
1891	6.21	4.90	4.92	2.18	1.67	4.00	3.00	2.75	2.31	5.45	1.93	3.58	42.90
1892	4.61	2.58	3.76	0.63	6.11	3.59	3.03	6.81	1.61	2.78	5.52	1.30	42.33
1893	2.19	5.77	1.95	3.34	5.76	3.31	1.95	8.00	1.44	3.27	1.77	5.22	43.97
1894	3.43	2.94	1.07	2.69	1.78	0.62	3.06	1.26	2.28	5.45	3.68	4.31	35.57
1895	3.84	1.23	3.12	3.36	2.80	2.98	3.76	4.96	1.41	9.10	6.67	2.65	45.88
1896	2.71	5.67	4.49	1.70	2.16	2.59	2.73	2.37	6.55	3.29	3.98	1.97	40.21
1897	2.80	2.06	2.69	2.95	4.89	4.19	4.76	3.99	2.27	0.43	6.66	4.39	42.08
1898	5.02	5.50	1.98	6.26	4.32	1.87	4.43	7.38	2.32	7.60	5.93	2.81	55.42
1899	4.54	3.75	6.98	1.76	1.33	2.59	1.97	2.19	6.11	2.41	2.25	1.52	37.40
1900	4.91	6.62	...	2.07	5.50	1.67	1.97	...	4.24	...	...	2.11	....
1901	1.68	...	6.56	8.88	...	...	3.48	2.83	...	2.77	2.90	7.37	....
1902	...	6.77	4.33	4.44	1.25	2.19	2.70	2.59	2.90	5.06	...	5.53	....
1903	3.77	...	6.25	4.91	0.27	10.48	2.27	3.82	...	...	...	2.43	....
1904	4.52	3.08	2.37	9.43	4.25	3.34	1.39	3.05	5.92	2.21	1.80	2.55	43.91
1905	4.20	1.62	2.71	2.79	1.59	6.42	0.39	3.14	6.67	1.32	2.45	4.10	37.40
1906	2.74	2.63	6.79	2.75	5.01	3.43	4.88	...	2.07	3.40	2.85	5.26	....
1907	2.76	2.18	2.18	3.59	2.96	...	2.91	...	8.16	2.29	5.99	4.36	....
1908	2.58	4.01	2.79	1.40	4.16	0.84	4.12	3.76	...	5.01	1.18	...	....
1909	4.85	4.82	3.09	3.82	1.70	3.34	2.60	...	4.15	1.49	...	...	

RAINFALL AT SALEM, MASS. Elevation, 20 feet.

(Sewage Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1910	...	...	...	...	...	...	...	...	...	...	...	1.81	....
1911	...	...	3.21	1.60	0.39	4.31	5.56	4.40	2.74	3.32	5.04	4.09	....
1912	1.84	2.74	4.43	4.33	5.52	0.40	5.90	2.86	3.08	2.03	3.20	4.74	41.07
1913	2.61	3.29	4.46	5.33	3.74	0.82	2.68	2.94	2.72	6.70	2.05	3.18	40.52
1914	3.83	2.59	4.14	6.80	2.75	2.14	2.82	2.50	0.46	1.50	2.93	3.58	36.04
1915	6.30	3.40	0.26	1.88	1.16	1.77	9.46	7.12	1.35	3.28	2.08	4.07	42.13
1916	0.97	3 66	2.44	5.44	3.44	5.37	4.08	2.94	1.97	0.99	2.51	3.09	36.90
1917	2.84	1.92	4.03	2.83	5.27	5.66	1.20	4.62	1.70	5.12	1.39	1.14	37.72
1918	2.30	3.54	1.67	4.52	0.46	3.02	3.31	2.30	11.21	0.93	2.29	3.81	39.36
1919	3.70	3.18	4.43	2.50	5.93	0.97	3.15	6.29	5.59	3.11	6.17	1.53	46.55
1920	1.79	4.74	3.28	6.15	5.87	6.37	1.53	1.45	3.58	1.05	5.92	4.33	46.06
Av. 9 yrs.	2.91	3.23	3.24	4.42	3.79	2.95	3.79	3.67	3.52	2.74	3.17	3.28	40.71

RAINFALL AT SAVOY, MASS. Elevation, 2 000 feet.

(Hoosac Mountain.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.77	2.69	6.95	2.79	3.68	1.48	3.30	2.42	4.15	5.53	3.77	3.06	43.59
1914	2.85	3.37	2.10	3.21	2.53	2.49	4.51	5.48	0.46	1.84	1.43	1.73	32.00
1915	5.26	4.80	0.44	0.92	2.20	3.20	10.16	8.29	4.22	3.69	2.26	6.26	51.70
1916	3.30	4.69	3.70	3.23	3.92	5.80	6.93	3.12	4.72	2.26	4.24	3.37	49.28
1917	3.26	3.19	4.14	2.20	4.48	5.18	4.63	4.58	1.40	6.90	1.76	2.42	44.14
1918	3.86	4.25	3.87	3.31	4.45	4.11	2.19	2.89	6.52	2.92	3.19	4.39	45.95
1919	2.46	3.26	4.81	2.18	8.77	2.69	4.36	4.78	7.61	2.90	4.98	2.44	51.24
1920	2.43	6.90	4.63	6.24	2.10	5.31	4.45	3.83	6.78	2.22	4.70	5.92	55.51
Av. 8 yrs.	3.40	4.14	3.83	3.01	4.02	3.79	5.07	4.42	4.48	3.53	3.29	3.70	46.68

RAINFALL AT SHARON, MASS. Elevation, 270 feet.
(Sharon Sanatorium.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1903	...	...	...	...	..	...	2.52	3.49	1.27	4.26	1.32	3.25	....
1904	4.60	3.00	3.00	8.62	2.66	1.97	2.51	2.35	6.22	2.68	1.39	2.71	41.71
1905	4.34	1.71	2.45	3.68	1.58	5.17	1.57	4.49	6.54	1.76	2.07	5.08	40.44
1906	3.12	2.98	6.11	2.17	6.31	2.13	7.07	2.00	1.56	2.06	2.13	.9.00	46.64
1907	4.38	3.36	2.24	1.77	3.54	1.25	1.25	1.35	4.46	3.15	2.22	3.64	32.61
1908	4.17	4.10	3.93	1.91	3.66	1.82	5.75	4.37	1.14	4.12	1.03	2.80	38.80
1909	4.16	5.46	3.93	4.77	2.10	2.04	1.15	2.06	0.37	1.20	7.80	3.21	38.25
1910	4.86	4.17	1.06	2.60	1.46	4.19	1.63	1.43	1.63	1.60	4.78	2.39	31.80
1911	2.81	2.95	3.09	2.77	1.49	4.30	4.55	7.28	3.42	3.09	6.00	3.14	44.89
1912	3.97	2.38	5.35	3.63	3.85	0.55	3.32	2.97	1.01	1.51	3.51	5.93	37.98
1913	3.88	2.92	4.91	4.67	2.75	1.35	2.61	3.26	3.07	7.74	2.49	3.48	43.13
1914	4.15	3.72	4.14	6.17	2.70	1.21	3.09	3.70	0.26	1.84	2.98	3.48	37.44
1915	8.99	3.96	0.03	2.72	2.04	5.80	4.47	5.37	0.63	2.84	2.91	4.64	44.40
1916	0.97	5.43	4.41	4.15	2.99	4.87	7.68	2.21	1.59	2.00	2.13	0.71	39.14
1917	2.64	1.86	4.02	2.05	5.31	4.96	0.83	8.01	2.49	6.15	0.54	2.15	41.01
1918	3.46	3.85	2.12	3.91	3.47	2.89	4.18	1.51	8.44	0.93	2.15	3.98	40.89
1919	3.62	3.27	4.99	3.35	5.66	2.53	5.89	5.70	8.71	3.44	5.34	2.18	54.68
1920	4.06	8.76	4.80	5.97	3.39	6.41	3.39	2.27	3.04	**1.20**	**6.02**	**3.62**	52.93
Av. 17 yrs.	4.02	3.76	3.56	3.82	3.23	3.15	3.58	3.55	3.21	2.78	3.26	3.65	41.57

RAINFALL AT SHELBURNE FALLS, MASS. Elevation, 300 feet.
(Power Construction Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	6.11	2.68	1.21	3.88	6.10	0.29	2.00	2.31	2.73	....
1915	3.15	4.44	0.11	2.31	1.22	2.14	9.06	9.48	2.60	2.85	2.57	4.23	44.16
1916	1.82	5.41	2.94	3.22	3.75	3.81	4.10	2.48	5.78	0.66	4.80	2.87	41.64
1917	3.46	2.11	2.79	2.22	4.91	6.24	2.37	2.89	0.59	8.24	0.56	2.23	38.61
1918	2.83	1.69	2.51	2.72	2.67	3.46	1.90	2.00	10.34	1.21	2.34	3.63	37.30
1919	1.48	2.45	4.20	1.83	8.05	0.79	2.72	3.57	4.58	2.57	5.70	1.62	39.56
1920	1.75	3.19	3.65	6.38	4.41	3.88	2.81	4.53	4.56	5.33	5.55	6.21	52.25
Av. 6 yrs.	2.42	3.22	2.70	3.11	4.17	3.38	3.83	4.16	4.74	3.47	3.58	3.47	42.25

RAINFALL AT SOMERSET, MASS. Elevation, 40 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.65	2.43	3.73	3.36	2.28	0.96	3.90	2.86	1.57	2.94	2.37	4.15	33.20
1915	8.16	3.96	0.03	1.61	2.02	2.49	2.78	4.76	1.51	2.88	3.16	4.09	37.45
1916	1.41	4.39	2.92	4.00	3.74	4.29	10.66	1.31	1.12	2.29	2.79	3.14	42.06
1917	2.87	2.55	3.87	3.04	5.20	4.33	1.12	3.95	2.95	5.95	0.24	1.80	37.87
1918	3.33	2.88	2.52	4.09	1.72	2.40	3.16	2.08	3.81	0.90	2.02	2.74	31.65
1919	4.76	3.87	4.22	3.04	4.30	1.84	5.47	6.74	7.10	2.82	4.07	2.54	50.77
1920	3.39	4.56	4.07	4.57	4.84	7.79	2.19	2.66	4.04	1.98	4.17	3.25	47.51
Av. 30 yrs.	4.07	3.95	4.27	3.96	3.41	2.96	3.27	3.37	3.41	3.59	3.52	3.73	43.51

RAINFALL AT SOUTHAMPTON, MASS. Elevation, 525 feet.
(Fomer Reservoir, Holyoke Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.21	5.65	4.32	5.13	4.00	2.01	3.18	3.20	0.19	2.03	4.32	3.14	40.38
1915	6.60	5.58	0.15	3.97	2.27	2.43	8.96	9.82	2.08	2.01	3.41	5.42	52.70
1916	1.81	6.44	2.83	4.44	3.24	5.89	5.42	2.06	8.04	1.55	3.79	2.97	48.48
1917	4.57	2.36	4.19	2.24	3.40	5.23	1.84	3.07	0.72	9.37	1.03	4.30	42.32
1918	3.81	1.85	1.58	2.90	2.86	4.30	2.88	3.84	6.67	1.43	2.93	3.47	38.52
1919	2.30	3.25	6.13	2.54	8.38	1.75	4.66	3.00	4.02	2.56	5.75	2.06	46.40
1920	2.48	5.17	3.41	6.18	4.93	6.79	2.30	6.25	8.01	1.96	6.66	6.93	61.07
Av. 24 yrs.	3.70	3.99	4.13	4.13	4.07	3.95	4.21	4.65	4.24	3.83	3.50	4.07	48.47

RAINFALL AT SOUTHBOROUGH, MASS. Elevation, 260 feet.
(Sudbury Dam No. 5, Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.86	4.18	4.34	4.88	2.80	1.84	3.48	3.86	0.24	1.62	2.56	3.64	37.30
1915	6.08	3.40	0.02	2.54	1.48	3.39	8.86	6.22	0.87	3.06	2.76	4.85	43.53
1916	1.51	5.92	4.02	4.15	3.44	4.90	5.18	2.26	2.02	1.37	2.23	3.20	40.20
1917	3.20	2.65	4.69	2.26	4.89	4.26	1.04	6.65	1.45	5.41	1.23	2.88	40.61
1918	3.49	3.50	2.38	4.10	1.06	3.64	3.82	1.73	8.07	0.97	2.80	3.46	39.02
1919	3.47	3.43	4.70	2.82	4.65	2.11	5.70	3.42	4.91	1.95	6.08	2.06	45.30
1920	3.06	6.15	4.72	5.12	3.27	7.23	1.97	1.57	3.62	0.88	5.75	4.98	48.32
Av. 22 yrs.	3.55	3.99	4.20	3.77	3.14	3.39	3.51	3.22	3.45	2.76	3.06	3.74	41.78

RAINFALL AT SOUTHBOROUGH, MASS. Elevation, 250 feet.
(Cordaville, Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.27	4.25	5.13	5.85	3.61	2.06	4.54	3.90	0.39	1.60	2.73	3.59	41.92
1915	6.83	4.12	0.07	2.51	1.92	4.09	8.21	6.06	1.19	3.00	3.22	5.53	46.75
1916	1.57	6.21	4.08	4.46	3.45	4.79	5.47	2.01	1.97	1.65	2.55	3.36	41.57
1917	3.87	2.77	5.21	2.34	5.43	4.31	1.20	7.10	1.51	6.43	1.47	2.90	44.54
1918	3.76	3.76	2.63	4.74	1.25	4.13	4.13	1.71	9.36	1.12	3.19	3.87	43.65
1919	3.84	3.65	5.55	3.26	5.06	1.94	6.55	3.98	5.80	2.37	6.32	2.07	50.39
1920	3.51	6.44	4.39	5.41	3.44	6.62	1.96	1.46	3.87	0.92	5.84	5.41	49.27
Av. 27 yrs.	3.97	4.17	4.37	4.10	3.41	3.60	3.69	3.71	3.94	3.45	3.83	4.08	46.32

RAINFALL AT SOUTHBRIDGE, MASS. Elevation, 720 feet.
(Hatchet Brook, Southbridge Water Supply Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	1.85	2.97	7.21	4.80	9.22	0.51	4.26	3.81	1.97	1.81	4.70	4.17	47.28
1913	3.04	2.54	5.02	5.38	3.78	1.95	1.04	5.27	3.73	6.35	3.02	3.40	44.52
1914	2.11	3.97	2.41	5.54	3.35	2.04	2.31	3.34	0.20	2.66	2.45	2.86	33.24
1915	6.18	3.57	0.16	3.32	2.87	3.45	5.46	7.33	1.57	2.74	1.48	4.14	42.27
1916	1.69	5.42	1.32	2.95	3.23	5.02	5.70	1.84	3.68	2.14	3.85	2.95	39.79
1917	3.62	2.73	3.72	1.96	2.45	4.57	1.09	5.76	1.60	6.67	0.89	1.48	36.54
1918	3.02	4.13	1 94	4.24	1.58	3.89	3.18	2.74	8.24	1.49	2.62	3.65	40.72
1919	4.30	3.36	5.95	3.12	9.16	2.54	4.76	3.52	8.29	3.09	5.74	2.13	55.96
1920	2.43	5.47	4.33	6.29	4.38	7.17	3.82	2.19	7.79	1.01	5.16	6.33	56.37
Av. 9 yrs.	3.14	3.79	3.56	4.18	4.45	3.46	3.51	3.97	4.12	3.11	3.32	3.46	44.07

RAINFALL AT SPRINGFIELD, MASS. Elevation, 105 feet.
(City Engineer's Office.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	5.16	3.64	0.07	1.62	1.80	1.69	8.77	7.57	3.26	3.22	2.30	6.13	45.23
1916	1.08	2.99	1.40	2.18	2.33	4.01	4.28	2.76	5.59	1.52	3.01	2.32	33.47
1917	1.97	2.60	2.87	1.61	3.75	3.55	5.37	8.84	1.04	5.68	0.75	1.97	40.00
1918	3.58	2.00	2.98	2.69	2.92	4.07	2.94	2.18	6.18	1.04	2.79	3.50	36.87
1919	1.70	2.86	5.58	2.70	5.84	1.98	3.49	3.26	5.82	1.31	5.11	1.56	41.21
1920	1.33	2.08	2.94	4.20	2.93	5.37	3.57	5.12	6.32	0.52	4.55	5.10	44.03
Av. 28 yrs.	2.58	2.70	3.39	2.90	3.31	3.15	4.11	4.39	3.92	3.35	3.05	2.96	39.81

RAINFALL AT SPRINGFIELD, MASS. Elevation, 200 feet.
(U. S. Arsenal.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.23	3.55	4.97	4.81	3.72	2.55	3.71	2.94	0.31	2.46	2.70	3.01	37.96
1915	5.73	5.35	0.15	2.25	1.63	2.83	6.04	5.51	2.60	2.77	2.26	5.68	43.80
1916	1.40	4.99	3.22	3.49	3.04	3.98	4.58	2.31	4.54	1.32	2.70	3.08	38.65
1917	3.57	2.73	3.57	1.58	4.06	3.11	3.72	7.04	0.94	4.46	1.90	1.49	38.17
1918	3.73	3.13	2.18	2.98	1.47	3.39	1.76	3.14	5.40	0.68	2.10	5.09	35.05
1919	1.54	3.44	5.32	2.76	5.58	2.06	3.76	2.56	4.72	1.67	4.91	2.16	40.48
1920	2.90	3.34	2.19	3.46	2.40	7.03	2.90	2.80	4.18	1.52	4.06	2.16	38.94
Av. 73 yrs.	3.30	3.57	3.64	3.22	3.85	3.61	4.26	4.35	3.57	3.90	3.53	3.43	44.23

RAINFALL AT STERLING, MASS. Elevation, 500 feet.

(Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.00	3.51	4.45	4.65	2.77	1.91	3.80	4.59	0.15	1.82	2.39	4.00	37.04
1915	5.48	3.29	0.05	1.70	1.65	2.78	8.57	6.14	1.74	2.91	2.97	5.05	42.33
1916	1.55	5.72	3.03	3.73	1.90	6.26	4.67	1.62	3.76	1.25	3.22	2.84	39.55
1917	3.24	2.90	4.07	1.65	3.94	4.47	1.37	3.26	1.01	6.29	0.91	2.94	36.05
1918	2.67	4.51	1.97	3.15	1.17	3.96	2.13	3.02	6.94	1.26	3.25	3.86	37.89
1919	3.17	3.69	5.69	2.70	6.81	1.48	4.64	4.27	6.43	2.58	6.29	2.30	50.05
1920	3.17	5.77	3.87	6.26	4.11	6.36	4.53	2.92	7.07	0.67	5.76	6.35	56.84
Av. 24 yrs.	3.37	3.82	3.96	3.60	3.32	3.68	3.85	3.85	3.63	3.17	3.33	3.98	43.56

RAINFALL AT STONEHAM, MASS. Elevation, 160 feet.

(Spot Pond, Metropolitan Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.36	3.77	4.64	6.52	2.64	2.26	2.93	3.21	0.24	1.52	2.68	3.37	37.14
1915	6.42	3.49	0.04	3.33	1.54	5.24	8.48	8.29	0.84	3.08	2.46	5.30	48.51
1916	1.55	5.71	4.41	5.26	3.92	5.59	3.28	2.32	1.80	1.38	1.84	3.19	40.25
1917	3.41	2.56	4.56	3.22	4.72	4.16	1.22	6.33	1.79	5.95	1.10	2.80	41.82
1918	3.56	3.51	2.46	4.31	1.37	2.67	3.63	2.18	9.42	1.13	2.05	4.07	40.36
1919	3.38	3.41	4.44	2.98	5.26	1.48	4.27	5.44	5.41	2.60	6.09	1.65	46.41
1920	3.18	7.70	4.16	5.74	4.98	7.15	1.88	1.37	3.50	1.12	5.53	4.70	51.01
Av. 22 yrs.	3.65	4.00	4.15	4.07	3.18	3.63	3.26	3.41	3.67	2.75	3.05	3.69	42.51

RAINFALL AT TAUNTON, MASS. Elevation, 50 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.70	3.51	4.92	5.22	2.65	1.17	3.52	2.74	2.24	2.51	3.57	5.45	42.20
1915	9.93	4.24	0.05	1.86	2.74	1.35	4.26	5.47	1.79	3.01	3.32	6.69	44.71
1916	2.11	4.94	3.82	5.12	4.13	4.60	9.41	1.60	2.36	3.27	2.87	4.27	48.50
1917	3.62	2.38	4.79	3.69	5.56	5.20	0.84	5.85	3.07	6.87	0.41	2.85	45.13
1918	5.91	3.49	2.42	4.86	1.83	2.99	6.83	2.69	8.89	0.89	2.52	4.14	47.46
1919	5.02	4.03	5.05	4.41	5.63	1.86	4.94	7.55	7.73	2.13	4.81	3.08	56.24
1920	3.84	6.83	4.87	5.54	5.21	6.48	2.90	3.39	3.43	1.67	4.03	4.12	52.31
Av. 46 yrs.	4.85	4.46	4.43	4.05	3.59	2.95	3.73	3.82	3.62	3.89	4.14	4.15	47.68

RAINFALL AT TEMPLETON (EAST), MASS. Elevation, 1 000 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1893	...	...	...	...	...	...	...	3.76	1.38	5.01	0.84	4.48	....
1894	4.72	3.60	0.63	2.83	1.37	0.32	1.88	0.54	3.68	1.57	3.43	3.74	28.31
1895	3.77	1.76	3.39	3.76	0.96	1.72	2.02	1.97	2.25	4.08	4.17	2.97	32.82
1896	1.62	4.36	6.15	0.25	1.68	1.01	2.99	2.35	4.83	2.75	2.26	1.01	31.26
1897	2.09	1.51	1.58	0.76	3.96	4.16	11.03	3.60	1.71	0.53	5.54	4.09	40.56
1898	4.31	1.96	1.04	3.10	2.77	3.74	2.18	7.92	3.60	5.99	6.43	2.16	45.20
1899	2.23	4.10	4.08	1.09	1.38	4.91	4.54	1.15	3.89	1.13	1.32	1.70	31.52
1900	4.11	6.90	4.23	2.57	2.15	2.83	2.42	3.61	4.56	3.43	5.52	1.54	43.87
1901	1.29	0.74	3.47	2.77	3.98	1.05	3.08	5.13	1.90	3.21	2.37	8.11	37.10
1902	1.46	2.31	3.81	3.43	1.96	3.57	4.28	3.06	3.11	4.65	0.32	6.01	37.97
1903	2.75	3.96	5.44	2.39	1.36	5.51	3.68	3.37	2.99	3.02	1.67	3.72	39.86
1904	2.91	2.12	3.29	4.15	3.02	3.60	1.78	3.71	4.16	1.00	0.83	2.10	32.67
1905	3.87	1.46	2.66	1.28	0.61	3.82	3.32	6.45	5.87	1.26	1.95	3.15	35.70
1906	2.01	2.74	4.48	1.00	6.56	3.62	4.90	3.44	2.17	3.69	2.10	3.84	40.55
Av. 13 yrs.	2.86	2.89	3.40	2.26	2.44	3.06	3.70	3.56	3.44	2.79	2.92	3.40	36.72

RAINFALL AT WALPOLE, MASS. Elevation, 175 feet.

(Standard Woven Fabric Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	3.06	2.27	4.74	3.05	3.82	0.51	3.23	2.98	0.94	2.11	2.84	3.47	33.02
1913	1.31	1.99	4.16	4.87	2.53	1.54	3.07	2.68	3.15	7.61	2.31	3.02	38.24
1914	3.89	4.08	4.07	5.51	2.70	1.20	3.41	3.78	0.43	2.09	2.96	3.79	37.91
1915	8.34	3.55	0.02	2.34	1.82	1.20	9.32	4.79	0.52	2.49	3.61	5.13	43.13
1916	1.05	4.87	3.27	3.84	3.44	5.14	7.48	1.92	1.44	1.75	1.63	3.14	38.97
1917	3.14	2.04	4.22	2.43	4.83	4.44	0.86	8.68	2.27	5.49	0.42	2.00	40.82
1918	3.21	3.06	2.12	5.22	1.79	2.70	4.81	1.36	9.38	0.64	1.20	1.80	37.29
1919	3.20	2.57	3.70	2.57	5.41	1.57	5.07	4.44	5.92	2.61	4.55	1.98	43.59
1920	3.21	6.34	4.18	5.26	3.31	6.16	2.57	2.86	2.46	0.19	4.86	4.33	45.73
Av. 9 yrs.	3.38	3.42	3.39	3.90	3.29	2.72	4.42	3.72	2.95	2.78	2.71	3.18	39.86

RAINFALL AT WALTHAM, MASS. Elevation, 30 feet.

(Boston Manufacturing Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.14	2.08	4.49	5.37	2.78	1.89	2.31	4.22	0.06	1.53	2.64	3.47	33.98
1915	6.52	3.20	0.00	3.76	1.51	1.81	10.76	5.58	0.85	2.77	2.89	5.28	44.93
1916	1.33	4.78	2.26	4.33	3.08	5.56	3.23	2.26	1.27	1.25	1.97	2.58	33.90
1917	2.58	2.22	3.38	2.08	4.48	4.32	0.78	3.55	2.63	6.33	0.60	3.04	35.99
1918	2.87	2.12	1.98	2.90	1.73	2.73	3.35	1.25	9.34	1.10	2.08	2.18	33.63
1919	3.50	2.97	4.06	2.34	5.06	1.18	6.23	4.39	7.88	1.73	4.04	1.42	44.80
1920	2.70	5.86	3.65	5.20	2.72	6.90	1.54	1.72	1.86	2.13	4.47	3.60	42.35
Av. 96 yrs.	3.31	2.92	3.63	3.75	3.53	3.18	3.66	4.17	3.47	3.65	3.89	3.27	42.43

RAINFALL AT WALTHAM, MASS. Elevation, 180 feet.

(Hobbs Brook Reservoir, Cambridge Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.03	2.80	4.67	5.13	2.50	2.10	2.42	3.35	0.30	1.70	2.65	3.37	34.02
1915	5.85	3.75	0.00	2.49	2.19	1.42	10.37	6.75	0.85	3.05	2.60	5.05	44.37
1916	1.52	5.01	4.03	4.50	3.10	6.12	3.30	2.00	1.50	1.10	2.28	2.67	37.13
1917	3.01	2.48	4.35	2.65	4.70	3.90	1.05	3.35	1.70	5.23	0.87	2.64	35.93
1918	3.24	2.21	3.30	3.00	2.20	3.28	4.00	2.05	8.10	1.00	2.15	3.29	37.82
1919	4.05	3.30	4.45	2.23	5.93	1.30	5.10	4.88	6.28	1.96	4.82	1.85	46.15
1920	2.82	5.69	4.20	5.02	3.20	6.82	3.09	1.23	3.69	1.16	5.27	5.79	47.98
Av. 26 yrs.	3.25	3.29	3.80	3.52	3.13	3.18	3.77	3.42	3.64	2.97	3.16	3.29	40.42

RAINFALL AT WALTHAM, MASS. Elevation, 20 feet.

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1880	3.10	3.88	3.03	2.14	1.69	1.06	8.32	4.38	1.64	3.06	2.20	1.39	35.89
1881	2.81	4.48	5.40	1.76	3.47	6.26	4.27	0.96	2.49	3.04	3.53	3.45	41.92
1882	3.64	3.67	2.48	2.51	5 20	1.90	2.52	1.32	9.59	2.28	0.73	2.17	38.01
1883	3.16	3.92	2.26	3.12	4.78	2.86	3.76	0.38	0.97	6.08	2.32	2.60	36.21
1884	4.29	6.26	4.19	3.61	2.91	3.54	5.27	4.55	0.63	2.67	1.95	4.76	44.63
1885	4.99	3.15	0.48	3.52	3.41	4.24	2.53	6.12	1.56	4.70	6.02	1.82	42.54
1886	5.12	7.83	3.06	1.76	3.28	1.33	2.72	3.12	3.14	3.10	4.74	3.13	42.33
1887	5.48	5.14	5.01	3.31	1.27	2.62	4.33	4.75	0.78	2.98	3.10	4.30	43.07
1888	4.26	3.58	5.63	3.18	4.48	1.95	1.70	6.91	9.28	5.09	7.53	5.99	59.58
1889	6.73	1.50	1.87	4.43	5.23	3.33	10.63	3.38	4.34	3.96	6.20	2.66	54.26
1890	2.18	2.97	5.89	2.48	5.76	2.59	2.13	3.05	5.50	10.28	1.35	5.05	49.23
1891	6.11	5.37	4.97	3.05	1.68	3.83	2.97	4.66	2.69	3.61	2.60	2.83	44.37
1892	3.76	2.07	2.97	0.91	6.11	4.30	3.27	4.00	2.48	3.15	3.86	1.25	38.13
1893	2.13	4.50	2.62	3.18	4.15	2.53	2.83	6.79	1.75	4.05	2.01	4.38	40.92
1894	1.66	1.53	1.08	2.24	4.61	0.10	3.00	1.37	2.04	4.72	2.66	3.46	28.47

RAINFALL AT WALTHAM, MASS. — *Continued.*

(Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1895	3.38	1.70	2.38	4.23	2.07	4.13	4.49	5.01	2.45	10.73	5.60	2.07	48.24
1896	2.03	6.03	3.36	1.50	1.88	2.55	2.72	2.37	7.74	3.41	3.25	2.06	38.90
1897	2.64	2.10	3.09	2.72	4.71	5.03	4.23	4.77	2.85	0.15	6.62	3.65	42.56
1898	4.48	5.30	1.11	6.36	3.44	1.73	5.68	7.18	1.80	7.42	5.62	3.21	53.33
1899	4.34	3.11	6.28	1.55	1.70	3.38	2.39	2.97	4.91	2.73	2.54	1.60	37.50
1900	4.54	8.54	5.21	2.36	3.52	2.99	2.70	2.30	3.60	4.28	5.22	2.81	48.07
1901	1.36	0.84	6.89	8.11	7.95	1.31	5.50	4.85	4.17	2.74	3.16	8.10	54.98
1902	1.89	6.32	3.75	4.52	1.18	2.53	4.02	3.80	4.81	4.85	1.12	4.48	43.27
1903	3.89	3.90	6.92	3.84	1.00	8.53	3.93	3.90	1.91	4.55	1.69	2.49	46.55
1904	4.30	2.62	2.58	9.64	3.25	3.14	1.69	3.54	7.01	1.88	1.96	2.78	44.39
1905	5.11	1.12	3.16	3.13	1.88	5.33	2.11	3.02	7.64	1.24	2.42	3.76	40.22
1906	2.59	2.76	6.02	2.54	5.22	2.83	5.11	2.58	2.95	3.04	2.99	4.93	43.56
1907	2.88	1.89	1.51	3.33	3.40	2.67	1.48	1.66	8.92	3.49	6.89	3.03	41.15
1908	3.83	4.05	3.52	1.97	3.99	1.14	3.53	4.23	0.90	3.07	0.87	2.91	34.01
1909	4.21	5.59	3.91	4.57	1.82	2.96	1.59	3.17	4.94	1.14	3.47	4.37	41.74
1910	5.11	4.95	0.82	2.38	1.52	4.59	2.33	1.14	2.99	1.60	4.33	2.21	33.97
1911	2.91	2.99	3.16	2.42	0.67	3.92	4.83	5.03	3.90	2.97	4.77	4.35	41.92
1912	3.16	2.75	6.27	4.26	5.04	0.31	4.38	2.82	1.93	2.56	3.20	5.62	42.30
1913	3.16	2.94	5.74	4.42	4.35	1.08	3.29	4.95	3.99	6.19	2.43	3.15	45.69
1914	3.31	2.17	1.69	5.51	2.78	1.92	2.46	4.88	0.07	1.81	2.47	3.51	35.58
1915	6.57	3.19	0.00	3.76	1.49	1.81	9.87	5.50	0.92	2.80	2.93	5.09	43.93
1916	1.16	4.77	2.26	4.33	3.03	5.79	3.31	2.10	1.30	1.20	1.85	2.78	33.88
1917	2.88	2.53	3.59	2.41	4.98	4.43	0.73	4.47	2.35	5.50	0.83	2.16	36.86
1918	3.01	3.57	1.74	2.84	2.00	2.68	2.99	1.64	9.52	1.02	2.08	3.06	36.15
1919	4.09	3.12	4.34	2.57	5.77	1.32	5.21	6.09	7.44	2.24	6.20	1.79	50.18
1920	2.25	5.86	4.65	5.77	3.55	7.28	1.78	2.23	3.38	1.39	6.01	4.85	49.00
Av. 41 yrs.	3.62	3.77	3.62	3.47	3.42	3.12	3.72	3.71	3.74	3.58	3.45	3.42	42.64

RAINFALL AT WAREHAM, MASS. Elevation, 60 feet.

(Onset Water Company.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	...	...	...	...	...	...	...	3.43	2.51	3.97	0.79	1.58	....
1918	3.06	2.94	2.32	4.48	0.91	4.80	2.28	2.07	5.05	0.98	2.45	4.25	35.59
1919	5.74	3.14	4.92	3.81	3.72	3.00	9.16	6.03	4.93	2.94	4.59	2.97	55.25
1920	3.49	7.12	6.35	5.49	5.15	7.87	1.96	2.58	2.26	2.51	3.63	4.42	52.83
Av. 3 yrs.	4.10	4.50	4.53	4.59	3.26	5.22	4.47	3.56	4.08	2.14	3.56	3.88	47.89

RAINFALL AT WARREN, MASS. Elevation, 650 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1911	...	...	...	...	...	...	...	...	...	4.02	3.98	...	....
1912	...	...	...	5.10	5.64	0.62	2.03	2.64	1.46	1.48	4.36	4.43	....
1913	3.88	2.33	5.60	4.71	3.91	0.92	1.48	3.37	3.18	6.03	3.39	1.70	40.50
1914	2.76	3.88	4.86	4.38	3.08	2.19	3.41	3.60	0.25	1.64	2.53	2.51	35.09
1915	5.41	3.74	0.21	1.14	**1.97**	**2.06**	**8.52**	**5.49**	**1.62**	**2.65**	**2.78**	**3.91**	39.50
1916	1.52	5.23	2.31	3.60	3.81	4.73	7.01	3.43	3.90	1.14	3.29	2.82	42.79
1917	2.95	2.79	3.59	1.50	3.89	4.04	0.89	5.41	1.24	5.92	1.62	1.52	35.36
1918	2.78	3.76	1.76	3.27	1.52	4.69	2.76	3.13	6.03	1.71	2.78	2.61	36.80
1919	3.43	3.24	5.44	2.60	4.62	1.12	7.56	3.43	7.18	**2.53**	**6.32**	**1.83**	49.30
1920	**2.09**	**5.14**	**8.78**	**5.61**	**3.68**	6.89	5.55	4.21	5.18	0.85	4.63	4.80	57.41
Av. 8 yrs.	3.10	3.76	4.07	4.61	3.31	3.33	3.39	4.01	3.57	2.81	3.42	2.71	42.09

RAINFALL AT WEBSTER, MASS. Elevation, 450 feet.
(Slater & Sons Mill.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.41	2.49	5.02	3.90	3.41	1.85	2.87	3.20	0.35	2.00	2.52	2.71	33.73
1915	6.75	4.99	0.10	1.64	3.40	1.84	6.59	6.44	1.48	2.47	2.13	4.88	42.71
1916	1.64	5.15	3.12	3.61	3.52	5.70	4.47	1.80	2.97	1.99	1.65	3.24	38.86
1917	2.91	3.95	3.88	1.72	3.73	4.76	1.61	6.75	1.56	4.77	0.59	2.49	38.72
1918	2.87	3.34	2.43	4.28	1.67	4.54	2.40	2.45	10.70	1.30	2.74	2.93	41.65
1919	4.07	3.49	5.34	3.70	4.39	3.38	3.16	4.90	5.59	2.33	5.37	2.76	48.48
1920	3.25	4.73	4.55	5.96	5.04	6.96	2.63	2.36	5.03	1.17	5.37	6.04	53.09
Av. 41 yrs.	3.64	3.92	4.12	3.28	3.35	3.11	3.63	3.76	3.57	3.30	3.30	3.74	42.72

RAINFALL AT WELLESLEY COLLEGE, MASS. Elevation, 160 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1886	**6.54**	8.82	3.50	2.39	3.16	1.37	5.28	3.37	3.07	3.08	4.55	5.33	50.46
1887	7.10	5.33	5.06	3.86	1.32	3.92	5.25	3.51	1.36	2.88	1.98	4.08	45.65
1888	4.41	3.72	6.41	2.96	2.14	1.06	4.17	6.72	9.05	4.68	7.92	6.83	60.07
1889	5.42	1.79	4.95	5.36	4.62	3.43	9.21	4.37	3.80	4.03	6.39	2.68	56.05
1890	2.50	2.82	8.20	2.86	5.69	2.06	1.88	2.69	7.62	9.95	**1.24**	2.74	50.25
1891	4.98	6.45	4.80	3.51	1.63	2.56	3.54	5.38	3.26	3.47	2.71	3.33	45.62
1892	3.60	2.95	2.87	0.83	4.68	2.96	3.35	5.37	2.57	1.71	5.18	1.11	37.18
1893	2.72	5.65	3.74	3.75	5.72	2.03	1.97	6.19	1.88	3.39	2.21	4.66	43.91
1894	4.39	4.97	1.24	3.89	4.06	...	...	...	...	...	4.07	3.12	....
1895	3.99	...	...	...	...	...	...	...	...	...	...	...	....
Av. 8 yrs.	4.66	4.69	4.94	3.19	3.62	2.42	4.33	4.71	4.08	4.15	4.02	3.84	48.65

RAINFALL AT WENHAM LAKE (BEVERLY), MASS. Elevation, 60 feet.
(Salem Water Works Pumping Station.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.12	2.57	2.94	5.77	2.25	1.61	2.16	2.57	0.41	1.32	2.63	2.86	30.21
1915	5.40	2.99	0.13	1.80	1.22	1.80	8.89	6.14	0.90	2.82	2.57	3.78	38.44
1916	1.28	3.04	2.28	3.81	3.53	4.99	2.90	2.03	2.60	0.81	1.98	3.49	32.74
1917	3.13	2.49	3.66	2.52	4.01	4.96	1.25	3.10	1.48	5.44	1.19	1.54	34.77
1918	2.42	2.83	2.88	3.18	0.67	2.94	3.04	2.53	8.70	1.02	2.45	3.28	35.94
1919	3.45	3.08	2.93	2.41	5.62	0.89	4.47	5.46	6.96	2.54	5.62	1.36	44.79
1920	2.35	4.67	3.05	2.10	2.99	6.47	1.66	2.08	4.02	0.79	5.24	3.87	39.29
Av. 47 yrs.	3.43	3.32	3.66	3.53	3.45	3.46	3.75	3.76	3.51	3.62	3.91	3.27	42.67

RAINFALL AT WESTBOROUGH, MASS. Elevation, 298 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.50	4.94	5.80	5.06	3.32	2.23	5.76	4.31	0.25	1.65	3.00	3.08	41.90
1915	**6.83**	**4.12**	**0.07**	**2.51**	**1.92**	**4.09**	11.43	6.06	1.46	2.77	2.88	4.98	49.12
1916	1.46	5.60	2.84	3.72	3.58	5.79	5.14	1.73	2.32	1.66	2.04	3.00	38.88
1917	1.97	**2.77**	2.18	2.04	4.93	4.33	1.11	7.42	1.36	6.86	1.00	3.15	39.12
1918	3.34	2.50	3.69	3.63	2.41	5.07	4.98	2.76	10.31	1.19	3.19	3.21	46.28
1919	3.66	3.43	5.26	3.39	5.93	2.54	4.15	3.81	6.03	1.88	6.92	1.80	48.80
1920	3.14	7.26	4.60	5.11	3.50	7.74	2.27	2.06	2.68	3.44	6.80	5.10	53.70
Av. 46 yrs.	3.68	4.02	4.23	3.41	3.34	3.28	3.65	3.94	3.37	3.70	3.75	3.47	43.84

RAINFALL AT WEST BROOKFIELD, MASS. Elevation, 630 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Dec	Nov	Annual
1913	3.31	2.34	5.81	4.81	3.79	1.39	1.25	2.69	3.37	6.05	3.35	1.95	40.11
1914	2.84	3.88	3.79	4.05	3.23	2.38	2.84	4.49	0.22	1.78	2.07	3.01	34.58
1915	5.78	3.58	0.15	1.27	1.97	2.06	8.52	5.49	1.62	2.65	2.78	3.91	39.78
1916	1.76	5.08	2.77	3.15	3.84	6.16	7.27	2.97	3.77	1.42	3.43	3.51	45.13
1917	3.08	3.03	3.75	1.65	3.78	5.15	1.20	7.30	1.30	6.66	1.95	1.02	39.87
1918	2.49	4.29	2.01	3.15	1.38	4.96	5.00	3.25	6.18	1.79	2.60	2.30	39.40
1919	3.45	3.25	4.75	2.77	6.44	0.48	8.30	3.36	9.00	2.57	5.95	1.97	52.29
1920	2.09	5.14	8.78	5.61	3.68	6.11	5.05	2.30	6.63	0.74	4.29	5.64	56.06
Av. 8 yrs.	3.10	3.82	3.98	3.31	3.51	3.59	4.93	3.98	4.01	2.96	3.30	2.91	43.40

RAINFALL AT WESTFIELD, MASS. Elevation, 475 feet.
(West Parish Filters, Springfield Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.56	4.07	5.87	6.27	2.95	2.88	3.13	2.54	0.24	3.08	3.55	3.66	41.80
1915	7.52	4.80	0.27	3.38	2.08	4.20	5.23	8.22	2.05	2.45	3.89	6.91	51.00
1916	2.01	6.75	3.72	3.50	3.48	5.27	4.44	2.11	6.72	1.54	3.62	3.91	47.07
1917	4.24	4.15	4.89	2.32	4.84	4.98	3.77	5.04	0.60	9.29	1.03	4.26	49.41
1918	4.27	3.59	2.37	3.11	2.18	3.84	1.67	4.11	6.07	1.48	3.32	4.19	40.20
1919	1.87	3.72	5.96	2.85	7.08	1.55	5.83	2.86	5.44	2.27	7.23	2.26	48.92
1920	2.50	5.63	4.24	6.61	2.68	8.73	4.19	8.59	8.72	0.80	6.75	6.85	66.29
Av. 15 yrs.	3.56	4.09	3.73	3.97	3.86	3.66	3.46	4.39	4.31	4.08	3.86	4.10	47.07

RAINFALL AT WESTMINSTER, MASS. Elevation, 980 feet.
(Meetinghouse Pond, Fitchburg Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	...	...	...	...	...	...	...	...	...	...	...	6.10	....
1916	1.80	5.47	3.25	3.66	3.86	8.25	5.98	2.32	3.72	0.82	2.52	2.40	44.05
1917	1.88	2.90	3.17	1.97	4.90	7.10	1.00	4.54	2.60	7.11	1.16	4.50	42.83
1918	2.80	3.97	2.15	1.87	2.58	5.45	2.75	2.94	8.81	1.99	2.77	2.06	40.14
1919	3.31	2.27	5.47	2.20	7.26	1.10	5.52	2.47	5.88	2.63	6.45	1.76	46.32
1920	2.80	4.61	4.82	6.95	4.15	4.67	3.92	2.85	8.12	1.10	5.30	4.82	54.11
Av. 5 yrs.	2.52	3.85	3.77	3.33	4.55	5.31	3.83	3.02	5.83	2.73	3.64	3.11	45.49

RAINFALL AT WESTMINSTER, MASS. Elevation, 880 feet.
(Wachusett Lake, Fitchburg Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	...	...	...	...	...	...	...	...	4.47	....
1915	6.70	3.81	0.04	1.98	1.67	1.47	12.01	9.49	1.85	3.35	3.66	6.83	52.86
1916	1.35	6.35	3.09	4.14	4.29	7.25	4.86	2.19	4.09	1.41	3.09	2.58	44.69
1917	2.86	2.99	4.61	1.36	5.63	4.84	0.95	1.67	2.54	7.26	0.93	4.99	40.63
1918	3.94	3.42	3.05	2.84	3.99	5.20	2.78	2.56	8.11	1.59	2.78	2.13	42.39
1919	3.61	2.73	5.95	2.23	7.51	1.10	4.02	3.38	7.79	2.68	6.87	1.74	49.61
1920	2.43	6.28	4.58	6.65	3.47	5.45	3.40	2.32	6.53	0.85	6.44	5.82	54.22
Av. 6 yrs.	3.48	4.26	3.55	3.20	4.43	4.22	4.67	3.60	5.15	2.86	3.96	4.02	47.40

RAINFALL AT WESTON, MASS. Elevation, 60 feet.
(Stony Brook Reservoir, Cambridge Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.43	3.34	4.97	5.37	2.69	1.79	2.50	4.49	0.17	1.69	2.50	3.41	36.35
1915	6.23	3.24	T	3.07	1.62	1.89	9.54	5.69	1.03	2.90	2.77	5.21	43.19
1916	1.18	5.69	4.22	4.28	3.28	5.62	3.76	2.29	1.39	1.28	1.96	3.24	38.19
1917	3.56	2.13	4.32	2.70	4.93	4.47	0.98	4.86	2.23	6.00	1.20	2.62	40.00
1918	3.00	3.71	2.14	4.07	1.29	2.86	3.30	1.29	9.39	1.17	2.18	3.38	37.78
1919	3.95	3.12	4.60	2.72	5.81	1.39	6.48	4.76	7.42	2.24	5.94	2.06	50.49
1920	3.32	5.30	3.90	5.54	3.40	7.00	1.75	2.12	4.61	1.34	5.88	5.03	49.19
Av. 31 yrs.	3.63	3.79	4.25	3.56	3.25	3.10	3.42	3.74	3.77	3.27	3.41	3.62	42.81

RAINFALL AT WILLIAMSBURG, MASS. Elevation, 550 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	3.36	2.64	5.85	4.26	4.35	1.16	1.83	2.10	3.32	6.05	2.93	2.90	40.75
1914	2.85	2.07	3.99	5.66	3.27	2.16	3.09	4.04	0.28	2.14	2.84	3.16	35.55
1915	5.72	4.75	0.11	2.65	1.34	2.83	9.34	8.06	1.46	2.58	3.18	8.22	50.24
1916	1.83	5.20	2.36	3.28	3.09	5.36	4.44	2.59	5.62	1.71	3.71	2.71	41.90
1917	3.82	1.87	3.92	1.96	4.80	5.24	3.08	4.20	0.91	8.46	1.96	1.99	42.21
1918	2.99	2.94	1.81	3.15	2.70	4.27	2.78	2.45	6.33	1.43	2.56	2.51	35.92
1919	2.11	3.41	4.56	2.54	8.17	1.62	4.36	3.20	4.29	2.52	6.03	1.92	44.73
1920	2.02	4.37	3.28	6.15	3.17	5.87	2.51	4.25	7.62	1.23	6.23	6.87	53.57
Av. 8 yrs.	3.09	3.41	3.23	3.82	3.86	3.56	3.83	3.86	3.73	3.26	3.68	3.78	43.11

RAINFALL AT WILLIAMSTOWN, MASS. Elevation, 711 feet.
(Williams College.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.31	1.94	3.90	5.65	1.94	2.21	4.33	5.10	0.53	1.72	2.14	1.94	33.71
1915	3.45	4.14	0.41	2.12	1.46	1.73	9.37	4.47	3.44	2.71	2.03	5.03	40.36
1916	2.05	1.53	3.51	2.48	3.52	3.62	5.30	2.45	5.20	1.79	4.21	4.28	39.97
1917	2.84	2.17	2.54	2.54	3.20	3.52	2.11	4.11	1.67	5.05	0.82	1.85	32.42
1918	1.89	1.86	2.37	2.45	4.04	3.04	1.78	2.31	6.44	2.75	1.83	3.42	34.18
1919	2.68	1.29	7.39	3.18	5.81	2.23	3 03	4.51	6.43	3.32	5.05	1.55	46.47
1920	1.54	3.99	3.30	4.72	1.85	1.15	3.89	4.96	4.91	2.22	4.17	4.45	44 15
Av. 44 yrs.	2.59	2.32	2.81	2.83	3.15	3.50	4.30	4.28	3.38	3.09	2.98	3.05	38.28

RAINFALL AT WINCHENDON, MASS. Elevation, 975 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.23	2.38	4.29	4.95	2.19	3.01	4.06	3.42	0.68	1.30	2.48	3.13	35.12
1915	5.55	4 10	0.05	4.01	1.59	1.90	8.88	5.43	1.20	3.03	2.38	5.90	44.02
1916	1.56	4.68	2.70	2.79	3.35	4.56	6.32	3.93	8.01	1.50	3.67	2.86	45.93
1917	3.62	2.28	3.63	1.70	3.76	5.47	2.92	8.64	1.00	5.91	1.83	2.38	43.14
1918	2.77	3.72	1.93	3.13	2.06	4.92	2.06	3.37	7.99	1.52	2.91	3.74	40.12
1919	3.16	2.66	4.89	2.40	6.55	1.06	4.99	2.56	5.24	3.27	6.34	1.71	44.83
1920	2.24	5.18	4.19	6.66	2.95	5.69	3.66	4.10	8.05	1.13	4.30	6.64	54.79
Av. 27 yrs.	2.97	2.99	3.54	3.19	3.15	3.46	4.02	4.18	4.18	3.04	3.23	3.47	41.42

RAINFALL AT WINCHESTER, MASS. Elevation, 90 feet.
(North Reservoir.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1913	...	...	...	...	3.87	1.82	3.01	4.16	2.82	7.13	2.31	2.83	....
1914	3.58	2.80	4.61	6.19	2.68	2.15	2.56	3.44	0.06	1.39	2.79	3.03	35.28
1915	5.10	3.79	0.00	3.30	1.60	1.77	10.66	6.65	0.76	3.24	2.39	4.34	43.60
1917	2.96	1.48	2.42	3.25	4.27	3.65	1.26	7.48	1.49	6.03	1.00	2.40	37.69
1918	1.25	1.90	2.20	1.10	0.32	3.05	6.83	1.85	10.28	0.77	2.54	2.93	35.02
1919	3.50	2.99	2.57	1.08	3.16	1.62	2.19	4.04	5.41	1.12	8.26	1.58	37.52
1920	0.95	2.80	2.30	3.64	2.80	3.62	2.15	2.66	2.12	3.20	5.86	2.68	34.78
Av. 33 yrs.	3.72	3.53	3.74	3.15	3.29	3.03	3.28	3.82	3.43	3.42	3.46	3.44	41.31

RAINFALL AT WORCESTER, MASS. Elevation, 400 feet.
: (Worcester Sewage Disposal Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.20	2.72	4.32	3.81	2.61	1.86	3.35	3.38	0.10	1.45	1.86	3.16	31.82
1915	6.16	3.11	0.00	1.65	1.64	1.51	7.67	5.85	1.48	2.62	2.81	5.19	39.69
1916	1.59	7.50	4.20	3.96	3.69	5.91	6.09	1.40	3.17	1.76	2.87	3.03	45.17
1917	2.93	3.20	4.50	1.67	3.57	4.88	1.22	6.27	1.04	6.93	0.93	2.78	39.92
1918	3.25	2.56	2.83	2.75	2.23	4.44	4.13	2.52	9.59	1.13	2.80	3.23	41.46
1919	3.82	2.88	6.62	3.16	5.40	1.75	5.46	4.46	6.38	2.12	6.41	1.78	50.24
1920	2.81	4.90	3.66	5.02	4.51	6.00	2.26	2.51	5.77	0.96	5.42	5.61	49.43
Av. 25 yrs.	3.21	3.65	4.04	3.38	3.08	3.36	3.57	3.51	3.83	2.89	3.26	3.58	41.36

RAINFALL AT WORCESTER, MASS. Elevation, 518 feet.
(U. S. Weather Bureau.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1892	...	...	...	...	6.34	2.22	4.70	5.51	1.74	0.58	5.82	1.00	....
1893	2.68	6.91	3.90	3.56	6.95	2.54	1.38	3.27	1.98	3.68	2.28	4.65	43.78
1894	2.98	2.84	1.41	3.60	4.63	0.73	3.75	1.47	3.16	3.96	**2.84**	**3.02**	34.39
1895	2.12	1.14	2.67	4.27	2.46	3.44	4.10	5.19	2.39	8.02	8.69	4.03	48.52
1896	1.93	5.69	6.90	1.23	2.78	2.75	3.55	2.56	7.45	3.90	3.02	2.25	44.01
1897	3.26	2.95	4.09	2.65	4.52	4.13	7.25	3.21	1.85	1.05	6.92	6.04	47.92
1898	4.28	4.78	2.37	4.19	**2.22**	**2.10**	**2.99**	**7.34**	3.05	5.95	8.36	3.04	50.67
1899	3.83	5.25	7.29	2.13	1.25	3.89	3.57	**1.62**	4.20	1.34	2.60	1.69	38.66
1900	3.13	7.45	6.27	2.56	3.47	3.98	3.49	2.76	2.21	**1.85**	**4.69**	2.50	44.36
1901	1.49	0.67	5.33	6.81	5.53	0.93	4.30	3.34	2.94	3.35	2.15	7.41	44.25

RAINFALL AT WORCESTER, MASS.— *Continued.*
(U. S. Weather Bureau.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1902	1.97	2.62	3.75	2.59	1.64	2.08	4.29	3.58	2.65	5.00	0.66	5.03	35.86
1903	2.75	2.87	5.15	2.28	0.88	7.44	3.01	3.31	1.14	3.21	1.89	2.30	36.23
1904	3.16	1.68	2.34	5.95	2.06	2.78	3.13	3.80	3.65	0.96	0.81	2.20	32.52
1905	3.73	1.27	2.65	2.46	1.07	4.73	2.44	2.15	6.16	1.47	2.16	2.86	33.15
1906	2.05	2.05	4.50	2.22	5.44	3.69	6.14	2.14	2.48	3.39	1.86	3.46	39.42
1907	2.69	1.61	1.37	2.39	2.72	2.73	2.37	1.25	9.46	4.79	4.57	4.16	40.11
1908	2.19	3.38	3.19	1.56	4.83	1.12	4.36	7.03	1.24	1.73	0.93	2.62	34.18
1909	2.39	4.94	3.43	4.80	2.63	3.00	1.14	2.29	4.07	1.08	1.49	3.32	34.58
1910	5.10	3.76	0.92	2.70	1.85	5.03	2.13	3.61	4.32	1.42	2.90	1.82	35.56
1911	2.40	2.21	3.84	2.17	3.66	1.96	2.92	4.77	5.74	3.53	3.27	2.45	38.92
1912	2.54	2.00	4.23	4.98	4.81	0.66	4.92	3.88	1.98	1.64	3.92	4.10	39.66
1913	2.60	2.43	4.27	3.16	3.68	2.14	2.56	3.00	5.04	4.26	2.20	2.07	37.41
1914	2.40	1.52	3.73	2.94	2.68	1.80	4.14	4.17	0.21	1.47	2.57	3.33	30.96
1915	5.74	3.39	0.04	1.50	3.24	2.19	7.01	5.84	1.02	2.44	2.35	3.49	38.25
1916	1.78	3.97	2.58	3.19	3.16	5.44	4.63	2.65	3.94	1.19	2.20	2.93	37.66
1917	2.44	2.18	4.18	1.62	2.88	4.03	1.12	5.55	0.90	5.51	1.07	1.37	32.85
1918	2.34	2.39	2.34	1.89	1.62	3.88	3.64	2.31	6.01	2.35	2.79	3.15	34.71
1919	2.99	2.05	4.87	2.03	3.86	1.61	4.72	3.49	3.89	1.96	4.87	2.06	38.40
1920	1.86	3.20	4.01	4.46	2.83	4.24	2.45	1.71	4.24	0.53	3.99	4.80	38.32
Av. 28 yrs.	2.82	3.11	3.63	3.07	3.19	3.04	3.63	3.47	3.48	2.89	3.14	3.29	38.76

RAINFALL AT WORTHINGTON, MASS. Elevation, 1 500 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	3.44	1.92	3.69	2.05	5.23	6.51	2.20	3.16	0.55	7.14	0.84	3.25	39.98
1918	3.85	3.52	2.56	1.99	2.62	4.44	2.98	2.92	6.09	1.99	2.83	3.61	39.40
1919	2.11	2.95	5.92	2.53	9.24	1.78	6.18	3.86	4.93	2.68	6.27	1.43	49.88
1920	2.50	5.42	4.66	6.86	2.01	6.75	2.43	5.14	8.52	1.75	6.51	6.20	58.75
Av. 4 yrs.	2.98	3.45	4.21	3.35	4.78	4.87	3.45	3.77	5.02	3.39	4.11	3.62	47.00

RHODE ISLAND.

RAINFALL AT BLOCK ISLAND, R. I. Elevation, 26 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.64	2.39	3.45	3.77	3.51	1.91	4.27	3.71	0.29	3.33	2.72	4.98	36.97
1915	8.25	3.38	0.33	1.83	3.11	1.00	1.59	4.49	1.35	5.18	2.24	4.91	37.66
1916	1.69	3.59	1.73	3.96	3.20	3.36	7.37	0.57	0.82	2.48	2.39	2.84	34.00
1917	2.98	2.70	4.85	2.14	3.01	2.51	2.90	0.73	2.80	5.02	0.19	1.90	31.73
1918	2.80	2.09	2.54	3.41	2.89	4.85	1.75	1.48	3.31	0.86	1.37	4.44	31.79
1919	3.76	3.81	4.16	2.49	3.42	2.45	4.94	4.87	3.78	3.13	3.54	3.53	43.88
1920	2.75	4.00	4.38	5.24	3.29	5.75	2.45	2.57	0.67	1.48	3.44	6.32	42.34
Av. 40 yrs.	3.83	3.89	3.99	3.62	3.55	2.64	3.17	3.33	2.78	3.62	3.65	3.89	41.96

RAINFALL AT BRISTOL, R. I. Elevation, 53 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.16	3.21	4.31	3.74	2.41	0.60	3.81	2.25	0.95	3.17	2.35	4.38	34.34
1915	10.10	3.85	0.02	1.94	1.73	1.99	1.99	4.54	1.66	2.00	2.24	5.24	37.30
1916	1.11	6.28	3.01	3.93	4.16	3.62	10.40	1.45	1.24	2.42	2.54	2.71	42.87
1917	2.74	2.32	4.76	2.75	5.00	4.25	1.18	3.69	2.91	5.09	0.39	2.27	37.35
1918	2.58	2.37	2.23	4.91	1.45	2.92	2.35	3.48	4.50	0.91	2.00	3.62	33.32
1919	4.54	4.19	4.26	4.03	4.50	4.47	5.16	6.87	6.58	2.30	3.84	2.93	53.67
1920	3.59	6.67	4.18	5.26	3.69	7.95	1.55	2.81	3.16	1.63	4.43	4.42	49.34
Av. 34 yrs.	4.02	3.84	4.05	3.70	3.41	2.88	3.05	3.38	3.15	3.39	3.41	3.77	42.05

RAINFALL AT BURRILLVILLE, R. I. Elevation, 400 feet.

(Wallum Pond.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.03	2.85	3.99	5.41	3.58	1.63	3.70	4.52	0.39	2.40	2.80	2.58	36.88
1915	7.14	5.46	0.17	1.87	3.47	2.27	8.69	6.46	0.92	3.21	2.61	3.51	45.78
1916	1.64	3.10	2.20	3.27	4.36	6.15	4.70	2.27	3.17	1.74	3.63	3.40	39.63
1917	3.75	2.00	3.56	1.78	4.23	5.06	1.94	5.70	2.03	6.25	1.03	3.10	40.43
Av. 8 yrs.	4.04	3.13	3.72	3.26	3.33	3.04	3.89	4.42	2.11	3.47	3.20	3.31	40.92

RAINFALL AT CRANSTON (FISKEVILLE), R. I. Elevation, 260 feet.

(Providence Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	...	...	3.02	2.96	5.18	4.90	10.10	1.82	0.93	3.13	2.17	3.32	....
1917	3.84	2.33	4.26	2.71	4.12	4.56	1.36	6.78	3.23	7.14	0.42	3.37	44.12
1918	3.98	3.43	2.21	4.54	2.31	3.96	4.73	4.54	9.62	0.87	2.65	3.80	46.64
1919	5.06	3.65	5.74	4.17	6.13	3.16	3.91	5.95	5.43	2.47	5.19	2.50	53.36
1920	3.30	5.81	5.02	6.33	4.45	8.26	3.57	3.14	2.97	1.57	5.65	5.49	55.56
Av. 4 yrs.	4.05	3.81	4.31	4.44	4.23	4.99	3.39	5.10	5.31	3.02	3.48	3.79	49.92

RAINFALL AT FOSTER (HOPKINS MILLS), R. I. Elevation, 450 feet.

(Providence Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.96	5.71	2.60	3.92	4.87	6.19	7.64	1.43	1.48	2.47	2.34	3.58	44.19
1917	3.92	2.34	4.76	2.72	4.31	4.72	1.34	6.48	2.32	6.63	0.53	3.47	43.54
1918	3.61	3.29	2.34	4.55	3.76	4.80	3.80	3.60	9.39	1.20	2.55	3.85	46.74
1919	5.13	3.60	6.03	4.57	6.22	3.32	6.51	6.52	6.18	2.35	4.74	2.78	57.95
1920	2.75	6.79	5.34	6.74	3.23	8.01	4.43	4.43	3.14	1.34	5.84	5.41	57.45
Av. 5 yrs.	3.47	4.35	4.21	4.50	4.48	5.41	4.74	4.49	4.50	2.80	3.20	3.82	49.97

RAINFALL AT GREENE, R. I. Elevation, 450 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.95	2.60	3.75	3.96	2.58	0.89	4.70	2.57	0.53	3.00	3.15	4.59	36.27
1915	8.59	4.79	0.08	1.26	2.10	1.21	5.59	6.34	1.11	2.44	2.84	5.16	41.51
1916	1.24	5.26	2.25	3.15	4.48	5.32	8.53	2.34	1.33	2.61	2.28	3.08	41.87
1917	2.89	2.20	4.73	1.74	3.33	4.27	1.66	7.52	2.87	5.71	0.28	2.65	39.85
1918	3.34	3.55	1 92	4.38	2.66	5.05	4.12	3.43	8.11	1.10	2.38	3.26	43.30
1919	4.44	3.14	5.83	3.54	4.58	2.75	5.58	5.88	6.34	2.38	4.53	2.15	51.14
1920	2.74	5.57	4.70	4.94	4.05	7.30	4.31	2.79	2.83	1.76	5.56	5.33	51.88
Av. 11 yrs.	3.78	3.64	3.62	3.56	3.13	3.08	3.99	4.08	3.23	2.91	3.52	3.83	42.37

RAINFALL AT HOPE, R. I. Elevation, 200 feet.

(Clyde Print Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1888	4.70	3.50	5.90	0.45	5.04	0.90	2.10	5.77	7.25	5.65	7.40	4.25	52.91
1889	5.25	1.20	2.00	5.60	4.85	2.25	9.60	6.15	4.85	3.40	5.65	1.80	52.60
1890	1.50	1.38	6.09	1.75	5.85	3.25	1.73	4.60	6.65	10.55	0.70	3.00	47.05
1891	8.70	6.40	6.50	4.90	1.80	3.60	2.75	4.40	2.70	5.50	4.00	4.80	56.05
1892	7.05	1.15	5.39	1.15	5.00	1.90	1.47	4.70	1.90	1.85	6.47	1.50	39.53
1893	3.50	8.10	5.85	5.25	8.95	4.20	1.00	4.55	2.45	4.82	4.40	4.75	57.82
1894	4.50	3.75	1.15	4.30	4.15	0.25	0.95	1.75	2.67	8.55	4.70	5.53	42.25
1895	5.20	1.50	3.02	5.60	2.50	4.10	6.18	2.25	2.94	10.20	4.70	3.15	51.34
1896	2.60	5.60	8.10	1.00	4.00	4.90	2.45	3.30	10.10	3.50	3.90	2.20	51.65
1897	6.70	1.90	3.55	3.60	5.15	3.25	8.20	5.55	0.80	0.10	9.55	6 70	55.05
1898	3.20	6.80	3.10	7.50	4.70	2.20	7.65	6.10	2.30	8.80	7.10	3.20	62.65
1899	4.30	4.00	6.75	2.90	2.75	4.60	4.75	3.55	9.25	1.20	4.05	3.60	51.70
1900	5.85	9.75	7.15	1.75	5.56	1.78	2.70	2.30	3.75	4.35	5.80	4.65	55.39
1901	2.15	2.00	10.28	12.15	8.00	0.80	5.65	3.63	5.65	2.75	3.30	9.45	65.81
1902	3.10	7.80	8.35	4.80	1.80	4.95	3.37	2.70	6.45	5.40	1.80	7.30	57.82

RAINFALL AT HOPE, R. I. — *Continued.*
(Clyde Print Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1903	5.70	8.60	10.10	5.50	0.10	7.90	6.60	5.90	2.30	3.89	2.00	4.30	62.89
1904	6.45	3.10	3.15	9.65	2.68	3.60	1.28	6.70	5.11	2.18	2.40	4.91	51.21
1905	3.42	2.11	2.83	4.03	1.52	6.36	3.62	3.24	5.71	2.57	2.30	5.43	43.14
1906	3.40	3.75	5.65	4.38	5.71	3.80	5.64	2.53	3.03	4.59	2.84	5.05	50.37
1907	3.26	3.15	1.93	4.26	4.50	3.16	1.16	1.14	11.47	3.62	6.76	5.66	50.07
1908	4.82	5.78	4.07	1.79	5.38	1.77	5.60	5.33	1.55	3.32	1.15	4.51	45.07
1909	3.89	7.35	3.54	5.70	3.09	2.45	1.01	3.17	3.51	1.53	3.47	4.40	43.11
1910	4.69	3.75	1.72	1.90	2.61	3.49	2.44	3.76	2.66	1.61	5.01	2.30	35.94
1911	3.14	1.95	3.08	3.60	1.51	3.09	3.88	4.78	2.04	3.80	6.72	3.55	41.14
1912	3.55	2.63	7.66	1.25	4.07	0.49	1.30	3.72	2.43	2.20	3.76	6.14	42.20
1913	3.48	3.38	4.65	7.00	2.25	1.73	2.43	2.92	2.85	6.28	2.72	3.90	43.59
1914	4.01	2.95	5.10	4.23	2.35	0.84	5.13	2.11	0.70	3.32	3.35	5.57	39.66
1915	9.07	4.45	0.07	1.51	1.90	2.05	5.77	6.07	1.17	2.65	3.08	5.65	43.44
1916	1.61	4.30	3.01	3.86	4.64	4.95	10.34	1.76	0.95	3.00	2.35	3.25	44.02
1917	3.85	2.65	4.65	2.45	4.20	4.45	1.05	6.44	3.05	6.75	0.45	2.89	42.88
1918	3.80	3.75	2.20	4.53	2.25	3.95	4.45	4.25	9.35	0.85	2.67	3.62	45.67
1919	4.95	3.32	5.44	4.23	5.35	3.08	4.47	5.13	5.64	2.20	4.40	2.24	50.45
Av. 32 yrs.	4.42	4.12	4.75	4.24	3.88	3.13	3.96	4.07	4.16	4.09	4.03	4.35	49.20

RAINFALL AT HOPKINTON, R. I. Elevation, 120 feet.
(Hope Valley.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.63	2.30	5.19	4.15	2.28	0.83	4.90	2.91	0.47	4.01	2.73	4.67	39.07
1915	10.74	4.85	**0.29**	1.50	**3.00**	1.35	3.25	8.00	2.18	3.19	3.26	5.30	46.91
1916	1.37	5.94	3.07	3.56	4.37	5.25	8.81	2.28	1.14	3.76	2.65	3.00	45.20
1917	4.11	2.78	6.53	3.41	3.78	5.13	2.85	7.41	4.02	4.51	2.85	1.85	49.23
1918	3.91	3.50	5.32	5.32	3.51	4.69	3.74	2.48	6.85	1.82	3.47	4.84	49.45
1919	5.64	4.77	7.26	4.62	4.64	2.04	6.58	6.89	8.46	2.91	3.09	3.14	60.04
Av. 10 yrs.	5.04	3.85	4.73	4.16	3.36	2.92	4.25	4.46	3.24	3.56	3.77	4.28	47.62

RAINFALL AT KINGSTON, R. I. Elevation, 250 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.97	3.51	4.95	6.22	2.82	1.01	4.79	3.06	1.13	4.56	2.79	6.03	44.84
1915	11.43	4.87	0.23	1.85	2.64	1.36	2.28	7.74	3.02	3.84	2.86	6.35	48.47
1916	1.84	5.96	3.68	4.57	4.60	5.77	11.75	2.77	1.05	3.22	2.91	4.86	52.98
1917	4.05	3.38	6.22	3.01	5.48	5.25	1.71	2.85	3.80	6.46	0.41	2.30	44.92
1918	3.77	4.79	2.72	5.60	2.09	4.71	2.53	2.61	5.46	1.42	3.05	4.81	43.56
1919	5.96	5.06	5.76	4.43	6.88	2.52	5.29	8.33	7.61	3.03	4.17	3.51	62.55
1920	3.75	5.21	5.08	6.12	5.07	7.42	3.11	3.04	2.32	1.70	5.35	6.05	54.22
Av. 32 yrs.	4.96	4.70	5.07	4.74	4.20	3.31	3.57	4.13	3.60	4.27	4.25	4.83	51.63

RAINFALL AT NARRAGANSETT PIER, R. I. Elevation, 22 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.23	3.56	4.36	4.81	3.08	1.12	4.94	4.13	1.01	4.26	2.59	5.14	42.23
1915	8.97	4.00	0.34	1.54	3.10	2.03	2.02	6.76	1.77	4.65	2.37	4.93	42.48
1916	1.66	5.45	2.71	3.95	3.49	4.73	10.69	1.50	1.65	2.78	2.52	3.25	44.38
1917	3.86	4.10	5.83	2.94	3.95	3.51	1.79	3.64	3.81	5.52	0.34	2.23	41.52
1918	3.32	3.96	2.78	4.99	2.44	4.88	2.57	**2.48**	**3.90**	**0.88**	**1.68**	**4.03**	37.91
Av. 36 yrs.	4.40	4.16	4.42	3.93	3.81	2.72	3.23	3.87	3.23	3.94	3.79	4.04	45.54

RAINFALL AT PAWTUCKET, R. I. Elevation, 220 feet.
(Diamond Hill Reservoir, Board of Public Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.22	3.37	5.00	5.13	2.76	0.97	2.82	2.67	0.41	2.80	3.91	4.19	38.25
1915	7.60	4.44	0.07	2.32	1.72	3.22	8.81	5.05	0.52	2.87	2.51	5.39	44.52
1916	2.19	6.03	3.39	4.17	4.49	5.98	8.25	1.84	1.33	2.47	2.66	3.35	46.15
1917	3.37	2.87	5.27	3.09	4.66	4.91	0.95	8.15	2.46	6.77	0.43	3.42	46.35
1918	3.95	2.81	2.66	4.09	2.49	3.48	2.63	1.93	9.27	0.77	2.29	3.88	40.25
1919	4.81	3.43	5.53	3.28	5.25	1.95	5.99	4.64	5.36	2.32	3.73	2.24	48.53
Av. 19 yrs.	3.72	3.75	4.48	4.16	3.33	2.93	4.05	3.47	3.70	3.37	2.98	4.26	44.20

RAINFALL AT PAWTUCKET, R. I. Elevation, 40 feet.
(Filter Beds, Board of Public Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.42	3.76	5.15	5.02	2.38	0.75	3.45	2.76	0.57	3.08	2.82	4.57	38.73
1915	7.29	3.90	0.09	2.47	2.14	1.64	7.74	5.71	1.18	2.26	1.96	5.08	41.46
1916	1.64	6.66	3.06	3.63	4.73	5.53	7.69	1.10	0.83	3.21	2.00	3.24	43.32
1917	3.06	2.09	5.26	2.98	4.26	4.40	0.89	6.18	2.60	6.29	0.42	2.69	41.12
1918	3.95	2.93	2.70	4.60	2.75	3.91	3.84	2.38	9.06	0.61	2.49	3.92	43.14
1919	5.18	3.65	5.36	3.66	4.37	3.24	3.99	6.61	5.76	1.96	4.30	2.48	50.56
Av. 19 yrs.	4.28	4.16	4.37	4.05	3.17	3.13	3.54	3.55	3.60	3.21	2.79	4.60	44.45

RAINFALL AT PAWTUCKET, R. I. Elevation, 140 feet.
(Masonic Building, Board of Public Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.55	3.59	4.76	4.98	2.53	0.89	3.51	2.81	0.58	2.88	2.92	4.70	38.70
1915	7.54	3.76	0.07	2.87	2.25	2.13	8.47	5.77	1.10	2.20	2.54	5.05	43.75
1916	1.71	4.61	1.70	4.10	4.84	5.29	9.21	1.07	0.93	2.82	2.05	2.68	41.01
1917	3.02	1.93	4.29	2.34	4.42	4.96	1.01	6.30	2.67	6.47	0.35	2.33	40.09
1918	4.00	2.73	2.34	4.15	2.53	3.80	4.13	2.92	9.35	0.63	2.39	3.66	42.63
1919	5.11	3.56	5.11	3.50	4.35	1.51	4.04	6.45	6.55	1.93	4.95	2.40	49.46
Av. 19 yrs.	4.13	3.92	4.15	4.12	3.20	3.12	3.94	3.63	3.76	3.22	2.83	4.54	44.56

RAINFALL AT PAWTUCKET, R. I. Elevation, 90 feet.
(Pumping Station, Board of Public Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.39	3.72	4.83	4.89	2.35	0.80	3.40	2.66	0.55	2.80	2.85	4.50	37.74
1915	7.57	3.38	0.08	2.33	1.98	2.29	8.15	5.62	0.84	2.17	2.20	5.14	41.75
1916	1.57	6.48	3.45	3.72	4.42	4.70	8.41	1.85	0.83	2.73	2.14	3.51	43.81
1917	3.17	2.19	6.27	3 16	4.69	5.01	1.09	6.92	2.54	6.48	0.31	2.94	44.77
1918	3.71	2.56	2.73	4.55	2.42	3.08	3.52	2.34	8.82	0.63	2.27	3.83	40.46
1919	5.32	3.10	4.87	3.35	4.65	1.63	3.87	6.39	5.31	1.92	4.55	2.60	47.56
Av. 35 yrs.	4.32	4.41	4.25	3.75	3.76	2.85	3.87	4.04	3.72	3.67	3.56	4.22	46.42

RAINFALL AT PAWTUCKET, R. I.
(A. H. Keene.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.39	3.72	4.83	4.89	2.35	0.80	3.51	2.55	0.55	2.80	2.85	4.50	37.74
1915	7.72	3.23	0.08	2.32	1.99	2.29	8.15	5.62	0.84	2.17	2.20	5.14	41.75
1916	1.57	6.00	3.45	3.72	4.42	4.70	8.41	1.72	0.83	2.73	2.14	3.51	43.20
1917	3.17	2.19	6.27	3.16	4.69	5.01	1.09	5.83	2.54	6.48	0.31	2.94	43.68
1918	3.71	2.86	2.43	4.55	2.42	3.08	3.52	2.34	8.82	0.63	2.27	4.16	40.79
1919	4.99	3.10	4.87	3.35	4.65	1.63	3.87	6.39	5.31	1.82	4.65	2.60	47.23
Av. 19 yrs.	4.26	3.52	3.65	3.66	3.42	2.92	4.76	4.08	3.15	2.77	2.40	3.81	42.40

RAINFALL AT PROVIDENCE, R. I. Elevation, 162.5 feet.
(Hope Reservoir, City Engineer.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.17	3.50	4.28	4.75	2.31	0.72	3.69	2.69	0.65	3.07	2.74	4.11	36.68
1915	8.73	3.11	0.11	2.54	2.55	1.76	7.92	5.76	1.02	2.61	2.58	5.92	44.61
1916	2.33	7.09	3.85	4.94	4.79	5.20	7.95	1.32	1.05	2.92	2.51	3.93	47.88
1917	4.00	2.55	4.93	3.52	4.84	5.35	1.23	7.00	2.77	6.72	0.40	2.73	46.04
1918	3.79	3.32	2.18	4.60	2.28	3.99	5.58	2.63	9.79	0.53	2.45	3.98	45.12
1919	5.78	4.23	6.40	4.10	5.60	3.59	4.77	6.83	7.14	2.08	5.10	2.80	58.42
1920	3.03	5.92	4.85	5.84	6.30	8.14	3.38	3.54	2.33	1.65	5.53	4.99	55.50
Av. 89 yrs.	4.11	3.88	4.16	3.81	3.68	3.26	3.39	4.04	3.37	3.61	3.90	4.02	45.23

RAINFALL AT PROVIDENCE, R. I. Elevation, 275 feet.
(Fruit Hill Reservoir, Providence Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.24	3.79	4.69	5.02	2.05	0.61	3.58	3.07	0.44	2.70	2.68	4.47	37.34
1915	8.54	3.97	0.07	2.39	2.18	0.93	6.85	6.36	0.81	2.23	2.49	5.37	42.19
1916	1.54	5.35	2.68	3.53	5.24	5.68	6.85	0.81	0.81	2.58	1.84	3.65	40.56
1917	3.23	2.24	5.05	3.02	3.81	4.56	1.02	7.92	2.55	6.50	0.36	3.31	43.57
1918	3.99	3.01	2.20	3.99	2.44	4.11	2.65	2.58	9.32	0.66	2.27	3.39	40.61
1919	5.01	3.57	5.53	3.52	4.86	3.43	3.82	7.23	5.10	1.54	4.74	2.28	50.63
1920	3.15	5.78	3.80	5.60	4.38	7.82	3.38	2.90	2.22	1.22	5.45	4.63	50.33
Av. 12 yrs.	3.95	3.77	3.64	3.85	3.17	3.05	3.53	4.05	2.89	2.64	3.23	3.94	41.71

RAINFALL AT PROVIDENCE, R. I. Elevation, 25 feet.
(Pettaconsett Pumping Station, Providence Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.21	3.46	4.74	4.64	2.43	0.67	4.82	2.10	0.77	3.81	2.84	3.87	38.36
1915	9.52	4.19	0.00	1.85	1.94	2.00	5.52	5.63	1.44	2.62	2.60	4.80	42.11
1916	1.56	7.41	3.40	3.62	4.68	4.77	9.01	1.42	0.48	2.77	2.30	3.40	44.82
1917	3.39	2.32	5.52	2.87	4.07	4.50	1.48	6.68	3.23	5.91	0.32	3.25	43.54
1918	0.54	3.77	2.08	4.50	1.86	3.50	4.55	4.11	9.75	0.72	2.39	3.82	41.59
1919	4.86	3.74	5.66	4.04	4.66	4.10	3.87	5.72	5.93	2.53	4.58	2.29	51.98
1920	5.66	7.25	6.64	5.88	4.73	8.27	3.35	2.75	2.30	1.91	5.45	4.61	58.80
Av. 17 yrs.	4.62	4.32	4.36	4.00	3.10	3.29	3.58	3.98	2.91	3.64	3.97	4.06	45.83

RAINFALL AT PROVIDENCE, R. I. Elevation, 25 feet.
(Sewage Precipitation Works, City Engineer.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.05	3.12	4.21	4.39	2.19	0.66	3.76	1.93	0.74	3.40	2.89	3.85	35.19
1915	8.80	4.01	0.07	1.80	2.07	2.57	5.84	4.45	1.29	1.67	2.43	5.37	40.37
1916	1.60	5.90	2.80	3.99	4.10	4.79	7.91	1.05	0.81	2.45	2.07	3.90	41.37
1917	3.28	2.58	4.62	2.62	3.83	5.48	1.73	5.53	3.05	4.24	0.38	2.40	39.74
1918	3.44	3.71	2.43	4.79	2.07	3.24	4.57	3.64	10.22	0.72	2.22	3.22	44.27
1919	5.05	3.85	4.77	4.02	4.71	2.83	4.99	5.69	6.02	1.87	4.57	2.44	50.81
1920	3.45	4.54	3.55	5.68	5.58	7.77	3.04	2.29	2.30	1.52	5.09	4.63	49.44
Av. 12 yrs.	4.04	3.92	3.51	4.01	3.16	3.13	3.57	3.30	3.09	2.64	3.20	3.77	41.34

RAINFALL AT PROVIDENCE, R. I. Elevation, 182 feet.
(Sockanosset Reservoir, Providence Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.14	4.35	5.16	4.63	2.41	0.65	4.98	2.22	0.88	3.37	3.01	4.55	40.35
1915	9.71	4.12	0.04	2.41	1.92	2.90	5.51	5.57	1.20	2.56	2.44	4.18	42.56
1916	1.44	7.24	3.28	3.61	4.57	4.77	9.45	1.36	0.71	2.64	2.19	3.64	44.90
1917	3.26	2.58	4.82	2.66	4.06	5.07	1.61	6.48	2.91	6.19	0.37	3.39	43.40
1918	1.44	3.33	2.21	4.81	1.92	3.48	4.90	4.32	9.06	0.73	2.22	3.89	42.31
1919	5.21	3.85	5.46	4.05	1.53	3.81	3.56	5.68	4.85	1.87	4.75	2.43	50.05
1920	4.50	7.57	6.58	5.50	4.82	8.24	1.89	2.19	2.75	1.69	5.41	4.82	55.96
Av. 15 yrs.	4.26	4.09	4.50	4.32	2.97	3.57	3.64	4.08	2.76	3.50	3.96	4.05	45.70

RAINFALL AT PROVIDENCE, R. I. Elevation, 182 feet.

(U. S. Weather Bureau.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1905	2.45	1.18	1.98	3.09	1.62	5.63	2.64	3.00	5.70	1.88	1.57	3.92	34.66
1906	2.59	2.88	4.29	2.47	4.51	3.40	5.29	2.51	3.18	4.91	1.90	3.81	41.74
1907	2.63	2.36	1.78	4.24	3.72	2.22	1.06	0.88	8.66	3.44	4.60	4.96	40.55
1908	2.93	4.00	3.42	1.77	4.18	2.01	4.33	5.16	0.88	3.37	0.92	3.12	36.09
1909	3.06	5.80	2.86	5.07	2.09	1.61	0.58	2.50	3.28	1.25	2.95	2.70	33.75
1910	4.85	3.86	1.32	1.64	2.90	3.98	2.86	2.62	2.68	1.60	3.37	2.53	34.21
1911	2.71	2.38	3.16	3.14	2.04	1.86	3.23	4.86	2.01	2.79	5.61	3.01	36.80
1912	4.09	2.65	6.36	3.61	3.99	0.63	1.76	2.90	1.87	2.37	2.81	5.61	38.65
1913	2.90	2.97	4.30	5.32	1.84	1.19	2.29	2.36	2.90	5.45	1.96	3.46	36.94
1914	3.56	2.99	3.38	3.94	1.88	0.58	2.81	2.02	0.48	2.97	1.96	2.93	29.50
1915	6.86	3.30	0.07	1.58	1.82	1.29	6.35	4.48	0.88	1.86	1.67	3.80	33.96
1916	1.35	4.34	2.46	2.89	3.85	4.20	6.37	0.78	0.86	2.39	1.92	3.03	34.44
1917	3.01	1.97	4.14	2.62	3.39	4.33	1.09	5.90	2.28	5.02	0.31	2.10	36.16
1918	3.11	2.87	1.77	3.74	2.07	3.12	4.44	2.41	8.04	0.65	2.01	3.14	37.37
1919	4.34	3.09	4.31	3.32	3.79	3.23	3.68	5.14	5.80	1.49	3.79	2.11	44.09
1920	2.60	4.56	3.66	4.70	4.92	6.80	3.00	3.17	2.11	1.44	3.69	3.91	44.56
Av. 16 yrs.	3.31	3.20	3.08	3.32	3.04	2.88	3.24	3.17	3.23	2.68	2.56	3.38	37.09

RAINFALL AT SCITUATE (ROCKY HILL), R. I. Elevation, 440 feet.

(Providence Water Supply Board.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.88	6.06	2.15	3.44	4.82	5.79	5.90	1.05	1.31	2.65	2.42	2.99	40.46
1917	3.99	1.88	4.91	2.71	4.11	4.63	0.97	4.83	2.46	6.50	0.50	3.09	40.58
1918	3.38	3.91	2.15	4.25	3.42	4.33	4.05	3.64	8.59	1.09	2.64	3.74	45.19
1919	4.78	3.23	6.15	4.26	5.75	4.55	6.23	6.77	6.14	2.13	5.21	2.59	57.79
1920	3.07	6.00	4.63	6.46	4.38	6.60	4.60	3.85	2.55	1.26	5.67	5.17	54.24
Av. 5 yrs.	3.42	4.21	4.00	4.22	4.49	5.18	4.35	4.03	4.21	2.73	3.29	3.52	47.65

RAINFALL AT SCITUATE (SOUTH), R. I. Elevation, 280 feet.

(Providence Water Supply Board.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1916	1.80	5.88	2.37	3.76	4.61	5.57	7.24	1.25	1.09	2.45	2.33	3.33	41.68
1917	4.03	2.24	5.39	2.65	4.04	4.27	2.31	6.77	2.91	6.77	0.43	3.06	44.87
1918	3.48	4.15	1.91	4.90	2.60	4.58	7.73	4.99	7.97	1.01	2.60	3.65	49.57
1919	4.66	3.30	6.11	4.18	5.92	3.31	4.46	7.00	6.22	2.29	5.12	2.42	54.99
1920	3.12	5.64	4.66	5.63	3.99	9.03	4.71	3.67	3.45	1.31	6.15	4.48	55.84
Av. 5 yrs.	3.42	4.24	4.09	4.22	4.23	5.35	5.29	4.73	4.33	2.77	3.33	3.39	49.39

RAINFALL AT WOONSOCKET, R. I. Elevation, 160 feet.

(Woonsocket Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.02	3.38	6.03	5.86	2.42	1.12	3.85	1.98	0.44	2.47	2.69	4.22	39.48
1915	8.15	4.88	0.09	1.70	2.04	2.92	10.35	6.48	0.48	2.96	3.14	5.11	48.30
1916	1.77	6.28	2.39	3.79	4.84	6.10	8.36	2.20	1.25	1.53	2.15	3.11	43.77
1917	3.91	3.04	4.85	1.16	3.96	4.76	0.84	8.34	2.20	6.51	0.57	2.38	42.52
1918	2.00	2.54	2.68	3.25	3.03	3.29	3.38	2.94	8.71	1.07	2.29	3.90	39.08
1919	4.66	2.93	5.31	3.21	5.25	2.64	5.70	5.26	6.44	2.70	5.01	2.37	51.48
1920	3.37	6.39	5.63	6.87	4.41	6.85	3.54	3.22	3.24	1.27	6.45	5.27	56.51
Av. 35 yrs	4.38	4.14	4.50	3.87	3.89	3.06	4.29	4.03	3.84	3.74	3.85	4.03	47.62

CONNECTICUT.

RAINFALL AT BAKERSVILLE, CONN. Elevation, 690 feet.
(Nepaug Basin, Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	...	...	...	...	4.08	0.79	1.59	4.21	3.25	4.14	4.62	4.09	....
1913	3.51	2.06	5.80	5.23	3.99	0.97	1.81	5.10	4.69	10.80	4.07	2.60	50.63
1914	2.85	1.93	4.65	4.42	3.20	3.12	4.38	2.59	0.26	3.67	3.36	3.54	37.97
1915	7.36	4.82	0.06	2.07	2.63	2.77	6.94	8.72	3.74	3.33	2.67	6.28	51.39
1916	1.21	4.71	2.78	2.64	3.39	3.99	5.21	2.08	5.38	1.66	3.11	3.39	39.55
1917	3.66	2.44	3.78	2.52	3.56	6.18	2.84	5.51	0.55	7.98	0.97	3.05	43.04
1918	4.04	2.93	2.76	3.83	6.03	2.91	4.87	2.31	7.80	1.44	2.74	3.50	45.16
1919	2.82	3.20	7.16	3.13	7.13	2.15	3.69	3.94	5.65	2.80	5.36	2.55	49.58
1920	2.68	4.93	5.25	3.62	3.54	5.82	5.17	4.13	7.98	0.80	4.23	5.38	53.53
Av. 8 yrs.	3.52	3.38	4.03	3.43	4.18	3.49	4.37	4.30	4.51	4.06	3.31	3.79	46.37

RAINFALL AT BARNES, CONN. Elevation, 550 feet.
(Nepaug Basin, Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	...	...	...	4.36	4.32	0.82	2.19	3.52	2.95	4.92	4.95	4.53	....
1913	3.40	2.39	5.44	4.64	4.39	0.77	1.88	4.72	4.99	10.85	3.50	2.88	49.85
1914	3.45	2.45	5.17	4.16	3.48	3.38	4.34	2.68	0.35	3.57	3.59	4.45	41.07
1915	7.48	4.85	0.20	2.36	2.39	2.49	6.40	9.10	3.60	3.15	3.98	5.78	51.78
1916	1.19	5.30	2.69	2.71	4.10	4.93	3.72	3.23	5.11	1.67	3.19	3.17	41.01
1917	3.77	2.50	4.02	2.70	4.32	6.49	2.70	4.73	0.79	8.71	1.24	3.29	45.26
1918	2.78	2.69	2.92	3.43	0.90	...	...	...	...	...	...	...	....
Av. 5 yrs.	3.86	3.50	3.50	3.31	3.74	3.61	3.81	4.89	2.97	5.59	3.10	3.91	45.79

RAINFALL AT BRIDGEPORT, CONN. Elevation, 20 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.38	2.91	4.41	4.24	3.33	2.78	7.10	2.52	0.25	4.90	3.17	4.95	45.94
1915	7.67	6.30	0.29	1.88	3.04	1.48	4.93	6.97	1.73	3.53	1.60	5.53	44.95
1916	1.66	5.04	4.05	2.71	3.06	4.41	4.73	1.93	3.06	1.56	2.20	3.11	37.52
1917	3.27	2.36	6.49	2.79	3.55	3.48	2.97	3.38	2.35	5.44	1.15	3.59	40.82
1918	3.63	3.20	1.93	3.56	3.87	5.27	3.65	1.80	4.66	1.47	3.01	3.98	40.03
1919	3.61	4.14	5.11	2.28	5.15	1.24	5.01	9.50	7.77	3.91	4.30	2.89	54.91
1920	2.94	4.51	4.72	5.25	4.14	5.13	3.06	4.01	4.77	1.35	4.93	5.75	50.56
Av. 27 yrs.	3.95	3.98	4.44	3.85	3.72	3.15	4.50	4.50	3.76	4.02	3.41	4.30	47.58

RAINFALL AT CANAAN, CONN. Elevation, 600 feet.
(Falls Village.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.51	2.35	4.23	3.69	3.30	2.97	3.10	2.48	0.55	2.23	2.37	2.58	32.36
1915	5.77	5.54	0.12	2.56	2.90	4.65	7.97	7.41	3.74	1.96	2.07	8.89	53.58
1916	1.48	3.77	2.92	2.97	3.38	3.87	7.38	3.10	6.23	0.96	3.58	3.02	42.66
1917	3.19	2.58	2.90	2.08	2.99	4.75	1.86	3.01	0.40	6.43	0.95	2.28	33.42
1918	3.01	2.73	2.53	4.05	3.93	2.90	5.65	3.59	5.55	1.68	2.41	3.79	41.82
1919	2.94	2.47	5.65	2.32	4.52	2.93	5.73	2.96	4.72	2.22	6.31	2.23	45.00
1920	2.07	10.37	4.03	4.94	2.65	5.24	4.16	6.02	7.88	1.18	3.78	4.29	56.61
Av. 19 yrs.	3.18	3.81	3.44	3.09	3.99	3.61	4.98	4.17	4.17	2.82	3.35	3.98	44.59

RAINFALL AT CANTON, CONN. Elevation, 900 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.46	2.63	4.73	4.18	2.91	3.24	3.87	3.21	0.29	3.67	3.89	4.60	40.68
1915	7.18	4.61	0.19	2.37	2.42	2.92	6.60	8.32	3.28	2.88	3.45	5.54	49.76
1916	1.15	4.74	2.90	2.51	4.67	6.53	4.61	3.82	4.20	1.28	3.31	3.19	42.91
1917	3.02	2.75	2.92	2.73	4.32	6.81	3.72	4.48	0.78	8.52	1.24	3.51	44.80
1918	3.29	2.67	2.74	3.06	3.98	3.22	3.02	2.36	5.96	0.77	2.77	3.47	37.31
1919	2.65	3.49	6.81	2.88	7.81	1.36	3.33	3.29	5.02	2.98	4.66	2.45	46.73
1920	2.71	3.19	4.23	4.99	3.87	9.13	5.10	2.74	9.16	0.52	5.68	6.02	57.34
Av. 62 yrs.	3.62	3.71	4.07	3.53	4.22	4.15	4.53	4.73	4.17	4.47	4.18	3.78	49.16

RAINFALL AT COLCHESTER, CONN. Elevation, 370 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.30	3.04	3.81	4.98	2.45	1.69	5.07	1.89	0.42	3.06	3.10	3.94	37.75
1915	8.40	6.25	0.26	1.92	3.57	1.35	5.94	7.90	0.96	3.69	3.21	5.70	49.15
1916	1.76	5.25	3.41	2.41	5.01	4.65	6.69	2.57	2.00	2.22	3.67	3.22	42.86
1917	4.13	1.62	5.82	3.18	3.59	4.77	2.72	7.11	2.52	6.07	0.74	3.12	45.39
1918	3.41	3.87	2.61	3.93	3.20	4.73	2.95	3.22	8.98	1.52	3.39	4.14	45.95
1919	4.43	4.17	7.78	4.11	6.49	2.15	5.10	7.33	4.77	2.91	5.11	3.06	57.41
1920	3.37	4.11	5.11	5.89	4.51	7.44	5.01	4.10	6.22	1.34	5.89	6.37	59.36
Av. 29 yrs.	4.04	4.12	4.50	4.32	3.92	2.99	3.91	4.43	3.71	3.86	3.98	4.27	48.05

RAINFALL AT CORNWALL, CONN. Elevation, 1 300 feet.
(Cream Hill.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.79	2.42	3.92	4.03	3.75	3.77	3.51	2.85	0.63	2.56	2.80	3.01	36.04
1915	6.66	5.62	0.29	2.80	2.96	4.32	7.93	7.24	3.63	2.24	2.70	7.52	53.91
1916	1.86	4.02	3.76	3.58	3.01	3.90	5.22	2.87	5.85	1.24	3.35	3.83	42.49
1917	2.84	2.78	3.47	1.76	3.43	6.22	3.98	3.99	0.72	6.10	0.85	2.88	39.02
1918	3.90	2.66	2.30	3.86	4.44	3.23	3.77	2.76	6.99	1.78	2.95	3.97	42.61
1919	3.09	2.22	6.11	3.74	5.16	2.27	5.40	3.06	4.36	2.51	6.43	2.72	47.07
1920	2.78	4.42	3.47	5.46	3.14	5.76	4.89	5.44	6.03	3.17	5.67	5.77	56.00
Av. 24 yrs.	3.64	3.47	3.74	3.48	4.11	3.92	4.94	4.38	4.49	3.64	3.34	4.01	47.16

RAINFALL AT DANIELSON, CONN. Elevation, 300 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.90	3.00	4.32	4.43	2.28	1.47	4.29	2.75	0.45	2.70	2.65	1.60	33.84
1915	6.00	3.05	0.10	2.00	3.09	0.75	9.90	7.71	0.95	2.75	2.65	3.90	42.85
1916	2.30	5.25	3.60	2.32	4.60	6.12	7.77	3.30	1.95	1.65	2.18	3.50	44.54
1917	3.68	2.55	4.10	1.25	3.53	5.16	2.50	6.40	1.98	5.48	0.85	1.10	38.58
1918	2.05	3.10	1.00	2.30	1.41	5.43	3.25	4.37	8.86	1.50	2.10	3.60	38.97
1919	5.40	2.10	7.10	5.52	4.57	4.30	4.88	5.22	6.55	...	...	...	....
Av. 14 yrs.	3.90	3.45	3.44	3.05	2.96	3.04	3.56	3.97	3.85	2.99	3.15	3.82	41.18

RAINFALL AT ENFIELD, CONN. Elevation, 90 feet.
(Thompsonville.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1915	...	...	...	1.26	2.00	4.09	7.04	5.72	3.50	2.82	1.79	4.88	....
1916	1.37	3.49	1.64	2.16	3.06	4.60	4.96	2.06	5.09	1.49	2.99	2.87	35.78
1917	3.46	2.12	3.78	1.50	3.73	3.35	1.93	4.35	1.03	4.91	2.28	0.55	32.99
1918	3.30	3.00	2.16	3.52	2.40	3.70	3.31	4.35	5.71	1.07	2.61	3.88	39.01
1919	2.25	4.24	5.35	2.94	5.75	1.44	3.22	2.66	6.25	2.17	5.70	1.79	43.76
1920	2.49	3.24	1.93	4.67	3.23	8.09	3.34	2.51	8.03	0.77	5.32	4.69	48.31
Av. 5 yrs.	2.58	3.22	2.97	2.96	3.64	4.24	3.35	3.19	5.22	2.08	3.76	2.76	39.97

RAINFALL AT HARTFORD, CONN. Elevation, 159 feet.
(Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.09	2.21	3.88	3.93	3.13	2.10	4.56	1.93	0.33	3.45	3.01	3.92	35.54
1915	6.89	4.22	0.17	1.36	2.57	4.06	4.15	8.92	1.68	3.20	2.14	5.60	44.96
1916	1.00	5 23	2.50	2.83	3.34	4.42	4.09	4.64	4.11	1.67	3.19	2.90	39.92
1917	3.60	1.85	4.15	2.87	4.02	4.24	4.34	5.67	1.36	7.72	2.49	1.30	43.61
1918	3.49	2.91	2.18	4.24	2.50	3.83	3.41	2.37	5.60	0.85	2.69	3.95	38.02
1919	2.21	3.49	5.07	2.94	7.62	1.14	3.47	3.60	4.85	3.19	4.72	2.15	44.45
1920	2.55	3.85	3.08	5.88	3.70	7.34	5.29	3.11	9.12	0.80	6.05	6.18	56.95
Av. 53 yrs.	3.44	3.48	3.87	3.32	3.60	3.29	4.06	4.48	3.67	3.82	3.63	3.41	44.07

RAINFALL AT HARTFORD, CONN. Elevation, 159 feet.

(U. S. Weather Bureau.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1898	...	...	...	3.91	6.05	2.40	5.15	7.58	2.67	5.89	7.82	2.51	....
1899	4.25	5.17	7.75	3.23	1.71	3.07	6.26	1.92	3.60	2.98	2.11	2.01	44.06
1900	4.34	9.70	6.91	1.83	5.41	3.64	4.83	2.65	1.72	2.84	5.12	3.13	52.12
1901	1.85	0.88	6.93	10.68	7.20	0.86	3.23	7.57	5.04	3.60	2.49	10.32	60.65
1902	2.13	6.17	6.09	3.87	1.59	5.18	6.85	6.11	6.51	6.71	1.26	7.10	59.57
1903	3.06	4.13	6.53	2.28	0.88	10.55	5.73	7.79	3.22	2.94	2.62	3.20	52.93
1904	4.31	2.14	3.00	6.08	3.19	2.94	3.64	5.45	5.45	2.25	1.52	3.09	43.06
1905	4.64	1.79	3.35	2.57	1.25	4.85	2.71	5.08	3.43	2.23	1.77	3.47	37.14
1906	2.69	2.30	5.02	3.58	4.60	2.19	5.09	2.65	3.57	5.54	2.90	3.83	43.96
1907	2.94	2.48	1.33	3.24	3.35	3.44	1.86	1.03	11.56	4.53	4.74	4.70	45.20
1908	3.47	4.98	3.06	2.36	6.52	2.42	5.74	6.74	1.12	1.67	0.92	3.36	42.36
1909	2.80	5.47	3.64	7.21	1.99	2.23	1.59	3.35	3.83	1.40	2.01	2.83	38.35
1910	6.68	4.43	0.95	3.15	2.49	4.16	2.47	2.98	3.41	0.77	4.36	1.93	37.78
1911	2.77	2.64	3.89	3.18	1.22	2.55	2.97	5.56	2.00	7.30	4.18	3.36	41.62
1912	2.11	3.43	7.29	3.93	4.59	0.66	2.90	3.02	2.14	1.26	3.53	4.46	39.32
1913	2.82	2.33	4.86	4.62	3.99	2.07	1.83	3.89	3.56	9.25	2.12	3.59	44.93
1914	3.38	2.79	4.14	3.84	2.71	1.70	4.30	1.96	0.20	3.05	2.38	3.85	34.30
1915	5.70	4.30	0.29	1.53	2.53	1.51	6.97	6.83	1.29	2.74	1.75	4.78	40.22
1916	1.16	5.72	2.77	2.93	3.14	3.86	3.52	3.44	3.46	1.08	2.83	2.99	36.90
1917	2.90	2.20	4.12	2.47	3.66	4.02	4.07	6.92	1.27	5.30	1.37	3.22	41.52
1918	3.28	2.43	2.58	3.36	3.46	4.36	2.76	3.51	4.89	0.82	2.74	3.56	37.75
1919	2.95	3.39	6.10	2.79	5.70	1.54	2.44	3.05	4.30	2.95	4.69	2.06	41.96
1920	3.39	5.08	3.75	5.43	3.53	8.00	6.70	3.45	7.95	0.90	6.43	6.35	60.96
Av. 22 yrs.	3.34	3.82	4.29	3.82	3.39	3.45	4.02	4.32	3.80	3.28	2.90	3.96	44.39

RAINFALL AT HARTLAND (EAST), CONN. Elevation, 1 200 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1917	3.07	4.74	4.14	2.57	4.28	4.80	2.51	6.50	0.54	9.07	1.03	3.43	46.68
1918	4.41	2.39	2.65	3.94	3.40	3.41	2.44	4.86	5.48	1.27	2.94	3.87	41.06
1919	2.04	3.19	6.92	3.15	8.14	3.32	4.79	2.93	6.34	2.30	6.15	2.15	51.42
1920	2.72	5.31	4.58	5.60	2.69	9.12	4.04	4.75	8.08	1.10	6.31	6.40	60.70
Av. 4 yrs.	3.06	3.91	4.57	3.82	4.63	5.14	3.45	4.76	5.11	3.44	4.11	3.96	49.96

RAINFALL AT LAKE KONOMOC, CONN. Elevation, 180 feet.

(New London Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.45	3.23	3.70	5.74	2.23	1.06	3.83	2.45	0.10	3.50	2.75	4.02	36.06
1915	10.75	6.36	0.28	1.50	3.10	0.74	3.09	8.66	1.14	4.00	1.45	5.01	46.08
1916	1.64	6.24	4.79	0.81	4.55	5.63	8.45	1.70	1.35	2.52	2.37	3.87	43.92
1917	3.85	3.62	8.74	2.44	3.93	4.64	2.36	5.53	4.11	4.78	0.71	3.98	48.69
1918	3.72	4.85	2.34	4.89	4.28	4.49	2.68	2.04	9.18	1.50	4.11	4.46	48.54
1919	5.87	2.93	7.82	5.90	4.01	1.99	5.38	9.08	4.81	2.86	4.40	5.07	60.12
1920	2.86	4.25	4.67	5.84	2.72	5.54	4.21	4.13	2.59	1.75	5.79	5.61	49.96
Av. 7 yrs.	4.59	4.50	4.62	3.87	3.55	3.44	4.29	4.80	3.33	2.99	3.08	4.57	47.63

RAINFALL AT LYMAN'S STATION, CONN. Elevation, 450 feet.

(Nepaug Basin, Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	...	...	...	...	...	3.63	4.03	3.04	0.34	3.49	3.13	3.13	....
1915	5.49	3.97	0.13	1.73	2.32	2.71	6.12	8.06	3.15	2.75	3.65	3.85	43.93
1916	1.00	3.07	1.84	1.24	2.11	5.02	4.12	3.51	4.31	1.28	2.99	1.92	32.44
1917	2.07	1.47	2.49	2.68	4.53	7.48	3.13	4.76	0.26	7.86	1.03	1.68	39.44
1918	3.14	1.47	2.74	3.33	4.25	2.95	3.59	2.82	5.66	...	...	...	....
Av. 3 yrs.	2.85	2.84	1.49	1.88	3.00	5.07	4.46	5.44	2.57	3.96	2.56	2.48	38.60

RAINFALL AT MANSFIELD, CONN. Elevation, 640 feet.
(Storrs.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.90	3.67	4.69	4.27	2.40	1.23	2.47	1.48	0.45	3.22	3.02	3.32	33.12
1915	7.52	4.41	0.15	1.18	2.64	0.93	8.28	5.92	1.51	2.71	2.93	2.49	40.67
1916	1.46	5.98	1.92	1.93	4.43	4.48	10.85	0.93	2.49	2.33	3.30	2.60	42.70
1917	2.86	3.29	4.84	1.87	3.00	4.05	2.65	7.06	1.13	6.12	0.47	2.16	39.50
1918	3.71	2.32	2.37	3.08	2.74	4.29	3.01	3.87	7.77	0.93	0.91	3.58	38.58
1919	2.40	2.49	5.74	2.78	5.30	2.07	3.61	2.46	3.66	3.00	...	...	....
Av. 26 yrs.	3.36	3.74	4.10	3.36	3.26	2.85	4.28	3.78	3.60	3.55	3.25	3.75	42.88

RAINFALL AT MIDDLETOWN, CONN. Elevation, 125 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.34	5.12	4.52	3.21	1.66	1.48	4.30	1.95	0.22	3.46	3.11	3.54	34.91
1915	4.86	2.95	0.27	1.23	1.61	1.40	7.02	7.69	2.31	2.86	1.84	3.90	37.94
1916	1.04	5.82	3.48	3.06	4.11	3.97	6.57	4.55	2.66	1.47	2.56	3.42	42.71
1917	2.81	1.92	4.27	2.78	3.51	3.71	3.86	4.42	2.37	5.88	0.96	2.60	39.09
1918	3.80	2.29	1.64	4.80	4.71	4.34	4.40	2.11	5.50	1.13	2.65	3.31	40.68
1919	3.00	2.71	5.56	3.43	6.12	2.22	4.31	4.27	6.80	2.99	5.15	3.30	49.86
1920	4.44	3.20	4.28	6.26	4.50	6.66	6.97	3.25	5.08	2.73	6.38	6.39	60.14
Av. 62 yrs.	4.01	4.04	4.53	3.54	3.76	3.37	4.19	4.59	3.63	4.05	3.88	3.95	47.54

RAINFALL AT NEW HARTFORD, CONN. Elevation, 370 feet.
(East Branch Shed, Hartford Water Works.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1912	...	...	...	3.95	3.83	0.73	2.21	4.55	2.15	4.62	4.31	4.22	....
1913	3.36	2.25	5.95	4.50	4.67	1.28	1.28	4.93	4.14	9.18	3.96	2.50	48.00
1914	2.99	2.53	4.64	5.37	3.21	3.29	4.43	2.95	0.47	3.14	3.62	4.10	40.74
1915	6.81	4.71	0.21	2.93	2.15	2.59	6.63	8.89	3.59	2.98	3.67	6.12	51.28
1916	1.26	4.72	2.35	2.86	3.26	3.50	3.37	1.99	5.52	1.35	2.46	2.41	35.05
1917	3.47	2.43	3.90	2.61	4.32	4.85	2.46	5.39	0.58	8.16	2.22	1.70	42.09
1918	2.56	2.48	2.07	3.19	7.06	3.12	5.54	3.36	7.60	1.03	1.65	3.30	42.96
1919	1.58	3.01	6.10	2.13	7.18	1.81	3.39	3.51	4.87	2.22	5.40	1.59	42.79
1920	2.22	2.30	4.08	4.35	2.24	7.48	4.57	6.35	7.56	0.77	5.06	5.46	52.44
Av. 8 yrs.	3.03	3.05	3.66	3.49	4.26	3.49	3.96	4.67	4.29	3.61	3.51	3.40	44.42

RAINFALL AT NEW HAVEN, CONN. Elevation, 127 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.58	3.68	4.53	3.90	3.00	2.07	6.51	2.36	0.17	3.81	3.28	4.87	43.76
1915	8.59	6.31	0.25	1.86	2.72	2.94	3.90	6.60	1.35	3.30	1.90	5.78	45.50
1916	1.55	6.21	4.08	3.00	3.69	4.90	3.72	2.11	2.54	2.05	2.54	3.71	40.10
1917	3.34	2.16	6.21	3.00	3.45	3.36	3.35	2.53	2.23	4.68	1.08	3.90	39.29
1918	3.61	3.04	2.32	4.26	3.82	6.10	4.31	2.51	6.16	1.20	3.37	4.21	44.91
1919	3.17	4.22	4.55	3.71	6.16	2.19	3.75	7.02	7.09	3.62	4.30	2.78	52.56
1920	2.80	4.78	2.18	5.62	4.22	6.62	4.93	2.69	5.15	0.79	5.14	6.06	50.98
Av. 70 yrs.	3.81	4.02	4.04	3.52	3.88	3.17	4.32	4.48	3.63	3.75	3.56	3.72	45.90

RAINFALL AT NEW LONDON, CONN. Elevation, 47 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.26	2.79	3.01	4.03	2.65	1.83	4.26	3.30	0.33	3.60	2.31	4.40	35.77
1915	8.61	5.52	0.35	1.51	3.37	0.94	5.31	7.48	2.43	3.27	1.97	4.72	45.48
1916	1.64	6.01	3.07	2.39	2.95	4.28	7.13	1.58	1.62	2.98	3.17	3.77	40.59
1917	4.14	2.08	5.60	4.74	4.13	4.25	2.46	4.90	4.47	3.49	1.65	1.40	43.31
1918	4.81	4.46	2.32	4.24	3.77	4.88	4.15	1.41	6.66	1.44	3.01	3.64	44.79
1919	3.85	3.53	6.74	4.91	5.68	7.71	4.28	7.80	5.76	3.49	3.43	3.44	60.62
1920	2.70	4.12	4.25	5.15	3.16	6.24	3.33	5.26	2.35	1.34	5.23	5.29	48.42
Av. 50 yrs.	3.94	3.77	4.19	3.57	3.37	3.03	3.68	4.27	3.45	3.75	3.67	3.67	44.36

RAINFALL AT NEWTOWN, CONN. Elevation, 600 feet.

(Hawleyville.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.82	2.65	6.30	3.75	3.09	2.35	5.19	2.69	0.32	3.70	3.30	2.78	39.94
1915	5.81	5.77	0.24	2.51	3.71	2.65	6.87	**8.70**	3.10	2.12	2.59	**5.98**	50.05
Av. 17 yrs.	3.93	3.90	4.51	4.21	3.90	3.46	3.98	4.55	4.13	4.06	3.02	4.25	47.90

RAINFALL AT NORWALK, CONN. Elevation, 116 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.34	2.11	6.64	3.05	3.21	2.25	5.19	2.00	0.23	4.65	2.53	4.47	41.67
1915	6.38	4.88	0.23	2.18	2.71	3.07	4.00	7.61	1.90	3.48	1.48	4.94	42.86
1916	1.22	5.10	3.72	2.51	3.26	5.79	5.05	1.00	3.65	1.37	2.34	3.62	38.63
1917	2.80	1.75	4.36	2.04	3.14	3.78	3.15	2.37	1.53	6.74	1.42	3.18	36.26
1918	3.48	1.80	1.63	3.74	3.04	3.40	4.19	3.29	4.73	1.44	3.19	4.11	38.04
1919	3.59	3.90	5.28	3.40	4.61	1.84	6.58	7.20	5.15	5.15	3.92	3.19	53.81
1920	2.74	6.36	4.77	4.87	4.20	4.99	4.87	6.66	7.56	1.33	3.56	5.58	57.49
Av. 29 yrs.	3.49	3.62	4.22	3.50	3.94	2.96	4.08	4.91	3.60	3.89	3.34	3.91	45.46

RAINFALL AT NORWICH, CONN. Elevation, 150 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.27	2.46	3.57	4.18	1.86	0.92	3.64	2.75	0.37	2.88	2.48	3.59	32.97
1915	8.48	5.33	0.24	1.65	2.22	1.07	4.51	7.18	0.76	2.81	2.17	4.22	40.64
1916	1.30	4.37	1.69	3.88	4.19	4.09	7.32	1.27	1.70	2.03	2.37	2.79	37.00
1917	2.75	2.20	5.48	1.47	2.81	3.86	1.72	4.53	2.96	4.18	0.42	2.55	34.93
1918	2.78	3.46	1.50	3.86	2.92	4.49	2.84	3.29	8.04	1.03	2.96	3.47	40.64
1919	4.63	3.40	6.42	5.28	4.21	2.41	5.42	7.56	4.92	3.02	1.85	2.75	51.87
1920	1.81	3.94	3.06	5.65	3.71	6.71	3.65	2.21	3.01	1.29	5.31	4.65	45.00
Av. 50 yrs.	3.92	3.80	4.29	3.72	3.26	2.99	3.72	4.46	3.37	3.76	3.79	3.82	44.90

RAINFALL AT SOUTHINGTON, CONN. Elevation, 140 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.40	2.80	5.30	3.35	2.20	1.90	3.95	2.75	0.15	3.05	2.65	4.95	36.45
1915	7.15	5.40	0.20	1.50	2.20	1.55	6.85	7.55	1.40	2.70	2.50	5.90	44.90
1916	1.08	5.45	3.10	2.30	3.10	4.90	3.10	4.95	5.00	1.60	2.75	2.35	39.68
1917	2.03	1.60	3.10	1.95	3.20	2.70	1.40	5.05	1.20	6.30	1.00	4.10	33.63
1918	3.90	2.95	1.65	2.75	2.20	3.70	2.65	1.75	5.00	1.00	2.30	2.70	32.55
1919	3.25	3.00	5.80	2.45	7.05	1.45	2.95	2.45	5.30	2.35	4.35	1.90	42.30
1920	2.80	3.90	3.95	5.25	3.60	5.70	5.65	3.30	6.10	1.70	3.23	6.90	52.08
Av. 50 yrs.	3.77	3.85	4.19	3.15	3.39	3.07	4.17	4.46	3.49	3.52	3.45	3.86	44.37

RAINFALL AT THOMPSON, CONN. Elevation, 400 feet.

(North Grosvenordale.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.56	3.51	5.17	3.01	3.00	3.22	3.06	2.58	0.33	2.43	2.53	2.88	35.28
1915	7.21	4.82	0.12	1.97	2.65	1.01	7.58	7.54	1.18	2.74	1.91	4.27	43.00
1916	1.60	6.27	3.20	3.89	3.47	6.60	5.60	1.54	3.41	1.50	3.33	2.93	43.34
1917	3.38	3.76	4.60	1.99	5.01	5.16	1.44	5.40	1.17	5.89	0.73	2.51	41.04
1918	3.95	3.74	3.19	3.68	2.96	3.22	1.79	3.00	10.01	1.19	3.47	3.43	43.63
1919	5.22	3.69	7.20	3.93	5.24	2.70	4.28	4.25	7.06	3.67	5.84	2.67	55.75
1920	3.60	6.07	4.32	5.93	4.79	7.73	2.99	5.34	5.04	3.95	5.18	5.98	60.92
Av. 30 yrs.	3.86	4.05	4.22	3.49	3.41	3.23	3.67	3.86	3.57	3.30	3.57	3.82	44.05

RAINFALL AT VOLUNTOWN, CONN. Elevation, 260 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.14	3.95	4.55	3.97	2.20	0.88	3.98	2.75	1.18	2.99	3.00	4.01	36.60
1915	8.60	5.07	0.18	1.19	3.05	1.15	3.32	6.69	1.59	3.02	2.63	4.42	40.91
1916	1.07	5.01	2.23	3.03	5.05	5.13	9.71	1.84	1.82	2.88	1.44	4.39	43.60
1917	3.06	2.07	4.99	2.30	3.09	4.54	2.04	4.51	3.14	5.88	0.43	2.52	38.57
1918	3.35	3.31	2.32	5.09	**2.64**	5.06	3.99	3.13	7.24	1.18	2.53	3.38	43.22
1919	5.10	2.16	5.99	1.27	4.37	2.73	4.37	5.15	5.28	2.45	1.10	2.87	45.84
1920	3.12	5.02	4.46	4.04	3.12	.	. .	3.31	3.83	. . .	. . .	. . .	. . .
Av. 35 yrs.	4.40	4.28	4.33	3.84	3.47	2.83	3.75	3.86	3.67	3.82	3.81	4.28	46.34

RAINFALL AT WALLINGFORD, CONN. Elevation, 130 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.68	4.00	4.50	4.29	2.59	1.88	4.43	1.84	0.36	3.34	3.46	**4.91**	41.28
1915	8.83	**7.87**	0.12	2.22	2.56	3.46	3.35	6.27	2.15	2.01	2.08	7.05	47.97
Av. 58 yrs.	4.46	4.43	4.58	3.69	3.83	3.38	4.09	4.41	3.54	3.99	3.99	4.17	48.56

RAINFALL AT WATERBURY, CONN. Elevation, 400 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.87	3.10	6.09	3.87	2.81	3.29	6.04	3.55	0.29	3.18	2.98	5.38	44.45
1915	7.08	5.49	0.17	2.30	2.78	1.72	6.30	7.82	1.15	2.55	2.58	6.37	46.31
1916	1.05	5.88	3.84	2.34	3.40	5.01	5.19	5.08	2.97	1.10	2.98	2.87	41.71
1917	3.04	2.35	4.24	2.72	4.07	3.51	1.93	5.62	1.57	8.72	0.97	2.09	40.83
1918	2.78	1.62	**2.34**	3.24	4.64	4.68	**3.34**	**2.08**	4.83	1.94	2.42	**3.72**	37.63
1919	3.83	0.43	6.24	2.83	6.22	3.07	5.26	4.72	**6.40**	5.00	4.95	2.45	51.40
1920	3.69	10.00	4.10	5.79	3.18	7.13	7.43	4.27	5.25	0.74	4.50	5.67	61.75
Av. 34 yrs.	4.13	4.17	4.31	3.64	3.86	3.47	4.69	4.56	3.76	3.97	3.54	4.25	48.35

NEW YORK.

RAINFALL AT ALBANY, N. Y. Elevation, 97 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.91	1.85	3.44	5.78	2.30	1.59	2.25	5.30	0.47	0.84	2.19	1.84	29.76
1915	2.76	3.79	0.09	2.15	1.92	2.85	5.05	6.23	2.17	2.15	2.11	6.35	37.62
1916	1.80	3.23	3.99	3.52	2.71	2.24	2.98	2.32	3.96	1.54	2.88	2.70	33.87
1917	1.67	2.41	3.14	1.38	2.83	3.00	1.70	2.70	1.36	5.63	0.93	1.91	28.66
1918	2.57	1.35	1.89	2.48	2.78	2.30	1.59	3.42	5.37	1.67	2.54	2.16	30.12
1919	1.42	1.68	4.86	1.98	5.42	1.10	4.34	4.60	2.99	2.60	3.30	1.23	35.52
1920	1.73	3.36	2.72	3.90	0.73	5.21	4.85	2.71	5.24	1.53	4.44	4.12	40.54
Av. 95 yrs.	2.55	2.44	2.76	2.67	3.44	3.86	3.98	3.77	3.32	3.32	2.91	2.65	37.67

RAINFALL AT COOPERSTOWN, N. Y. Elevation, 1 250 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.28	2.56	3.77	4.44	3.65	5.56	5.33	5.56	1.63	1.88	2.38	2.34	41.38
1915	5.23	3.03	0.56	1.96	2.57	7.15	8.48	5.48	3.41	5.32	2.78	5.42	51.39
1916	2.79	3.71	4.60	3.61	4.47	4.95	4.84	2.62	7.57	2.12	3.89	3.26	48.43
1917	3.75	2.19	3.14	1.81	3.86	9.96	7.97	4.98	2.01	8.34	1.52	1.50	51.03
1918	3.51	**2.26**	**1.83**	3.98	5.32	5.29	3.99	6.27	5.11	3.97	1.68	2.63	45.84
1919	2.01	1.70	3.00	2.36	4.51	4.15	6.76	3.37	1.93	4.96	3.17	1.70	39.62
1920	1.87	3.64	3.38	3.79	0.97	4.34	5.00	5.97	7.30	1.24	4.49	3.68	45.67
Av. 67 yrs.	2.76	2.61	2.85	2.79	3.67	4.33	4.61	4.37	3.60	3.44	3.02	2.86	40.91

RAINFALL AT CORTLAND, N. Y. Elevation, 1 129 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	1.59	1.69	3.84	4.55	2.99	5.60	3.49	5.66	1.29	1.20	1.43	2.39	35.72
1915	5.62	3.44	0.59	0.80	2.60	4.47	8.04	5.98	5.15	5.35	2.20	3.70	47.94
1916	1.44	3.55	3.02	2.41	4.43	4.38	1.18	2.39	6.67	1.99	1.93	2.64	36.03
1917	2.41	1.51	1.98	2.17	4.23	8.66	4.82	5.17	4.12	5.54	1.15	2.26	44.02
1918	2.61	0.80	3.37	3.02	5.65	4.11	2.94	2.81	5.66	3.54	1.67	1.95	38.13
1919	2.65	1.54	1.91	2.31	5.18	2.12	4.43	2.46	1.14	3.59	3.49	1.42	32.24
1920	2.14	1.14	1.76	3.66	1.66	3.08	4.19	5.27	4.00	1.38	3.68	2.92	34.88
Av. 40 yrs.	2.62	2.29	2.63	2.88	3.73	4.12	4.36	3.75	3.57	3.62	2.83	2.92	39.32

RAINFALL AT BOYD'S CORNER RESERVOIR (CROTON WATERSHED), N. Y.

(New York Water Supply.) Elevation, 600 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.59	2.13	4.43	5.15	3.26	3.40	4.99	2.50	0.33	3.96	3.64	4.26	41.64
1915	7.21	6.47	0.19	3.46	3.51	1.84	6.27	10.11	3.87	3.67	2.20	7.13	55.93
1916	1.50	4.56	3.45	3.16	4.40	3.90	4.52	2.23	5.82	1.40	4.17	3.46	42.57
1917	2.98	1.99	4.20	1.66	4.00	3.21	2.92	2.93	0.89	6.60	0.66	3.23	35.27
1918	3.48	3.11	1.52	4.58	3.78	3.26	5.35	4.88	3.85	1.64	3.35	4.37	43.17
1919	2.91	3.12	7.08	3.01	5.37	1.88	7.12	4.51	4.94	3.34	5.93	2.85	52.06
1920	2.61	4.89	3.45	5.45	2.81	5.86	6.74	4.97	9.19	1.21	4.02	5.72	56.92
Av. 53 yrs.	4.08	4.11	4.32	3.70	4.00	3.51	4.62	4.71	4.20	4.13	3.75	4.16	49.29

RAINFALL AT MIDDLE BRANCH RESERVOIR (CROTON WATERSHED), N. Y.

(New York Water Supply.) Elevation, 400 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	3.99	2.22	4.62	4.31	2.63	3.04	5.29	2.56	0.40	3.56	2.82	3.94	39.38
1915	6.69	5.75	0.19	3.31	2.76	2.51	5.03	8.89	3.59	2.70	2.43	5.88	49.73
1916	1.52	4.42	3.25	3.06	3.63	4.42	5.00	2.18	5.20	1.30	2.73	3.03	39.74
1917	2.83	2.10	3.66	2.25	3.72	3.12	3.57	2.24	0.96	6.60	2.21	2.48	35.74
1918	3.97	2.85	1.64	5.76	2.24	3.01	5.03	3.62	3.99	1.63	2.40	4.06	40.20
1919	2.56	4.25	5.70	2.77	4.49	2.12	5.80	3.44	5.08	3.81	4.91	2.66	47.59
1920	2.72	4.70	3.62	5.16	2.76	5.39	6.31	2.72	7.11	1.23	3.89	4.25	49.86
Av. 43 yrs.	4.14	4.15	4.04	3.45	3.87	3.47	4.82	4.94	4.11	3.83	3.61	4.04	48.47

RAINFALL AT OLD CROTON DAM, N. Y. Elevation, 200 feet.

(New York Water Supply.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	4.10	1.98	4.22	4.33	3.15	3.13	4.78	1.73	0.21	2.97	4.12	4.83	39.55
1915	6.62	6.86	0.46	3.26	2.87	2.46	5.40	9.79	3.99	3.36	2.52	7.63	55.22
1916	1.71	4.71	5.15	2.84	2.91	4.66	6.74	3.12	5.47	1.12	3.41	4.17	46.01
1917	3.24	2.63	4.83	2.54	5.15	4.84	2.75	2.49	1.53	7.20	2.40	2.42	42.02
1918	4.72	3.09	2.28	7.38	2.98	4.63	5.96	4.49	3.72	0.92	3.36	4.41	47.94
1919	3.26	4.98	5.65	2.92	6.17	3.25	6.88	5.14	5.98	5.31	5.02	3.66	58.22
1920	3.29	4.67	4.26	5.86	3.51	6.46	6.56	2.84	6.67	2.27	4.46	4.87	55.72
Av. 53 yrs.	4.27	4.26	4.57	3.63	3.83	3.59	4.72	5.36	4.39	3.97	3.93	4.06	50.58

RAINFALL IN THE VICINITY OF NEW YORK CITY. Elevation, 97 feet.

(Central Park Observatory.)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.27	3.33	4.74	3.34	2.35	2.06	5.47	2.54	0.29	2.23	3.31	5.24	40.17
1915	7.94	6.01	1.25	2.58	3.27	3.85	3.01	7.26	2.38	2.26	1.64	4.28	45.73
1916	1.28	4.76	3.70	3.28	4.35	4.56	4.55	0.54	3.45	1.04	2.14	4.25	37.90
1917	2.96	2.08	4.46	2.71	3.83	3.83	5.01	1.56	2.68	6.81	0.86	4.25	41.04
1918	3.53	2.47	1.67	4.65	4.83	4.61	4.36	2.43	2.92	0.78	2.41	3.61	38.27
Av. 83 yrs.	3.45	3.49	3.73	3.55	3.88	3.73	4.14	4.51	3.60	3.77	3.45	3.71	45.01

RAINFALL AT SETAUKET, N. Y. Elevation, 40 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	5.28	3.07	4.30	4.23	2.55	1.57	5.20	1.56	0.23	2.87	2.25	5.42	38.53
1915	9.23	5.75	0.41	2.05	3.50	1.56	3.38	8.42	2.09	2.94	1.56	4.96	45.85
1916	1.35	4.62	3.40	2.58	3.12	4.08	7.22	1.08	3.34	1.51	2.41	3.55	38.26
1917	3.18	1.81	5.79	2.65	4.22	2.75	2.92	2.03	1.93	5.42	0.43	3.15	36.28
1918	3.46	2.45	1.40	4.42	3.67	4.06	5.38	2.62	7.84	1.32	2.94	3.51	43.04
1919	3.14	4.04	5.39	4.51	4.52	2.17	5.47	6.15	4.49	3.74	4.26	3.21	51.09
1920	3.26	6.65	4.23	4.91	3.75	6.34	4.55	4.40	4.57	1.83	4.95	6.33	55.77
Av. 35 yrs.	4.00	3.98	4.29	3.74	3.44	2.73	4.24	4.25	3.57	4.06	3.54	4.03	45.87

RAINFALL AT WAPPINGERS FALLS, N. Y. Elevation, 110 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	2.93	2.05	2.52	3.89	3.58	2.39	6.14	1.96	0.44	3.90	3.24	3.96	37.00
1915	5.89	5.41	0.38	3.23	3.52	2.91	6.25	9.35	2.99	3.00	2.27	8.86	54.06
1916	2.49	6.30	4.70	2.75	3.59	3.60	5.58	3.08	4.72	2.46	2.44	3.80	45.51
1917	3.49	3.48	2.84	1.62	4.10	5.13	2.72	4.48	0.70	5.53	0.52	2.60	37.21
1918	2.83	4.83	2.29	4.09	3.38	3.82	3.38	1.69	4.85	1.99	2.56	4.62	40.33
1919	2.79	3.31	5.39	2.42	4.66	1.37	6.10	4.30	3.89	2.53	5.39	2.50	44.65
1920	2.84	4.77	3.80	3.73	2.77	5.32	4.00	2.67	6.32	3.39	4.00	4.30	47.91
Av. 30 yrs.	3.72	3.98	3.79	3.66	4.37	4.15	4.71	4.63	3.76	3.93	3.20	3.81	47.71

RAINFALL AT YONKERS, N. Y. Elevation, 100 feet.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1914	8.28	0.13	0.50	3.35	2.85	1.25	6.31	1.70	0.25	3.90	5.00	6.88	40.40
1915	9.10	5.40	0.12	0.88	2.15	2.05	4.60	8.95	1.75	3.02	1.30	0.87	40.19
1916	1.30	7.50	2.33	2.28	5.18	6.15	6.14	1.20	2.40	1.25	1.44	3.95	41.12
1917	3.20	2.10	5.62	2.60	3.85	2.63	2.15	1.51	1.16	6.70	0.65	2.60	34.77
1918	3.10	2.50	0.78	1.90	1.75	2.28	1.68	1.30	2.90	0.60	3.25	3.15	25.19
Av. 41 yrs.	4.66	4.19	4.33	3.75	3.75	3.62	5.20	5.05	3.78	4.45	3.28	4.11	50.17

CANADA.

	Brome, Que.	Chatham, N. B.	Father Point, Que.	Fredericton, N. B.	Halifax, N. S.	Montreal, Que.	Point Lepreaux, N. B.	Quebec, Que.	Sherbrooke, Que.	St. John, N. B.	Whitehead, N. S.	Yarmouth, N. S.
1914	26.66	36.05	23.91	36.08	47.56	32.71	....	37.71	34.92	36.23	....	36.37
1915	30.21	48.81	33.89	41.51	62.86	29.23	....	32.78	34.85	46.39	24.06	37.27
1916	37.41	40.60	32.99	39.38	43.56	38.81	33.05	42.73	37.93	38.16	31.89	42.99
1917	42.04	48.73	36.90	47.95	52.13	44.62	40.81	48.12	31.90	46.43	39.86	50.06
1918	44.06	47.05	30.05	46.86	53.32	47.25	42.84	53.79	38.08	49.57	42.83	49.66
Av.	34.24	41.96	34.77	43.81	56.11	40.64	43.25	41.39	38.32	50.04	39.84	47.86
Years	41	45	45	40	50	47	30	48	14	58	31	39

ARGUMENTS AGAINST BOATING AND FISHING IN WATER-SUPPLY RESERVOIRS.*

To his Excellency the Governor:

The undersigned officers and past presidents of the New England Water Works Association, which comprises some 900 engineers and superintendents, most of whom are responsible for the care and protection of the waters supplied to the people of New England, respectfully submit this protest against the so-called Naphen bill, — House No. 589.

1. This bill grants to the inhabitants of Natick the right of boating and fishing on Lake Cochituate within the town of Natick.

2. We believe that such a grant is a step backward and a bad precedent.

3. Massachusetts has by long-continued, progressive effort reached such sanitary control of its public water supplies that the typhoid death rate, as recently recorded, is the lowest of any state in the country. This result has only been made possible by the untiring efforts of those who have been responsible for the purity of its water supplies, and, in our judgment, any legislation tending to loosen this sanitary control and to nullify the good work of the past is pernicious and rightly to be condemned.

4. Lake Cochituate — as it now exists — is the result of developments made by the City of Boston — the original natural lake, Long Pond, having been raised 8 ft. under authority of an Act of 1846 and 2 ft. additional under an Act of 1859. The lake comprises three ponds, extending northerly and southerly and lying in the towns of Natick, Wayland, and Framingham. From the southeast corner of the northern pond an aqueduct 13.3 miles long, with a capacity of 18 million gallons per twenty-four hours, leads to Chestnut Hill Reservoir.

5. At present, fishing from the shore is allowed by the Metropolitan Commission, in all parts of the lake except the northern division, — the one from which the aqueduct leads. The nearest point at which fishing can be carried on is about one third of a mile from the aqueduct intake. It is possible to supervise and regulate the use of the shores, although even this is attended with difficulties; but under present conditions it is wholly within the control of the Commission, and the permission can be promptly withdrawn should it prove necessary. The Act, now proposed, grants rights to boat and fish on the lake, including a part of the section of the lake adjacent to the intake of the aqueduct, and any infection of this water may reach the Chestnut Hill Reservoir in eighteen hours and the consumers within twenty-four hours; or, in other words, the conditions — if this bill becomes law — will be right for an explosive epidemic.

6. It is true that in recent years Lake Cochituate has been used only as auxiliary to the Wachusett supply, but from 1911 to 1919 water has been drawn from the lake in six of the nine years, for periods ranging from

* This letter was sent to Governor Coolidge of Massachusetts, requesting him to veto a bill which would have allowed boating and fishing in Lake Cochituate, a reservoir of the Metropolitan Water Works.

twelve to two hundred and ten days, and it may be necessary to put this supply in regular service at any time. Also if the present rate of increase of consumption in the Metropolitan district continues, Lake Cochituate will be necessarily used continuously after about 1925, unless some new supply is added to the system at great expense.

7. The proposed use of Lake Cochituate by the inhabitants of Natick for boating and fishing will, therefore, in our opinion, seriously jeopardize the health of the Metropolitan district. For such benefits as will accrue to Natick in recreation, the sanitary protection of one million people will be reduced, and this because it is impossible to so supervise such use of the lake as to prevent accidental or intentional contamination. Boating will mean easy approach to the location of the intake and possible short-circuiting of infection to the consumers; boats are frequently upset by accident or otherwise, if the users desire a swim; fishermen are more than likely to urinate in the water, and urine carries as many typhoid germs as fecal matter. It is impossible to provide such supervision as will guarantee the prevention of such happenings.

8. The fact that the water could be filtered and probably rendered safe is no argument. Chlorination as a disinfecting process might be practical without filtration, but would not be a complete safeguard, and would involve substantial expense. It is not logical to allow a few people to contaminate the water so as to make necessary a large expense to the many who will use it. As has been well said, "It is innocence and not repentance we want in our drinking waters."

9. On a certain Saturday of October, 1913, 500 cases of diarrhea suddenly developed in Peabody, Mass.; on the previous Thursday some men had been fishing on Spring Pond — a part of the water supply — and on Friday a shower had occurred. Investigation by the State Department of Health led to the conclusion that the epidemic was chargeable to infection of Spring Pond by the fishermen. In all, 1 500 cases developed. This is cited as an instance of the explosive possibilities of such chance contamination of a water supply, and, in our opinion, well illustrates the danger of opening Lake Cochituate to boating and fishing.

We respectfully urge that you veto Bill No. 589.

HENRY V. MACKSEY, *President.*
CHARLES W. SHERMAN, *Vice-President.*
FRANK A. BARBOUR, *Vice-President.*
FRANK J. GIFFORD, *Secretary.*
LEWIS M. BANCROFT, *Treasurer.*
HENRY A. SYMONDS, *Editor.*
LEONARD METCALF, *Past President.*
SAMUEL E. KILLAM, *Past President.*
FRANK A. MCINNES, *Past President.*
EDWIN C. BROOKS, *Past President.*
ROBERT J. THOMAS, *Past President.*
J. C. WHITNEY, *Past President.*

MAY 11, 1920.

WILLIAM M. STONE.

Mr. William M. Stone, 34 Pine Street, Attleboro, Mass., born August 4, 1826, died May 27, 1921, in his ninety-fifth year.

For thirty-six years he was Water Commissioner of Attleboro, Mass., retiring from office in 1910, and until his death was very much interested in the department.

He joined the New England Water Works Association, September 13, 1905, and although for the past two or three years he has not been able to attend the meetings, he was deeply interested in the Association, and enjoyed the Journals.

His mind was perfectly clear to the last, the end coming suddenly, as he was sitting, fully dressed, in his chair.

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New England Water Works Association
ORGANIZED 1882.

Vol. XXXV. December, 1921. No. 4.

SANITARY PROTECTION OF PUBLIC WATER SUPPLIES.

BY ALLEN HAZEN.*

I am going to speak to you to-day about the relations between water supply and disease, and about what is done and may be reasonably done to keep public water supplies from carrying disease, and from ever being in a position where those who take the water may have well-grounded anxieties as to the safety of the supply.

I propose to discuss this matter in very general terms, and with particular reference to the developments of the last years, that have put at our disposal new and most useful methods of control.

The progress that has been made has been so great that there are now few public water supplies in American cities that ordinarily cause disease among those who use them. The improvement in this respect as compared with conditions of thirty years ago is very marked. Conditions that were common and that were regarded with indifference in 1890 would be intolerable in 1921.

The question now presented is not so much how to keep our water supplies free from disease-producing qualities, for that question has been answered; but rather to see what precautions may best be taken to secure safety without duplicating to an unreasonable extent parallel lines of defense when this involves added cost and an unreasonable burden on the people who pay the bills.

The question is to be taken up primarily from the standpoint of surface supplies. Such supplies from rivers, lakes, ponds, and artificial reservoirs constitute a large part of the public water-supply systems of New England.

It is unnecessary to even mention to you at this time the ways in which these waters become polluted; and the reasons for preventing or removing the effects of the pollution. Our late president, W. T. Sedgwick, contributed greatly to the knowledge of these matters, and you are all familiar with them.

The general satisfactory conditions of public water supplies to-day may be largely attributed to the fact that knowledge of these matters is so

* Of Hazen, Whipple & Fuller, New York.

generally distributed that there are men in practically every community who know where the danger lies and are on the lookout for it.

The principal methods of protecting these supplies, and those who use the water, from the effects of injurious pollution may be briefly enumerated.

1. Ownership of Catchment Areas.

Ownership permits trespassers to be excluded, and theoretically gives complete protection. But we well know from practical experience that even ownership does not quite accomplish this result. Trespassers do get on the land and at the water. Even the water-works people themselves, including necessary inspectors, and the men who must be sent upon the ground to plant the forests and to cut the old trees and to repair fences, may sometimes be careless; and their presence represents some danger to the water supply. If the catchment area is large, roads and even railroads must be permitted to cross it, and in every case something of full efficiency is lost. The ownership of land to control the quality of the water supplies is very general in American water-works systems. It is more often partial than complete. Parts of catchment areas from which pollution is particularly feared have been purchased. Often those parts that could be purchased have been bought and other parts remain in private ownership. Ownership of land is a useful method. Sometimes it is indispensable. Frequently it is costly.

2. Sanitary Supervision of Those Who Live on Catchment Areas.

This applies to areas that are not owned by the water works. Some supervision is attempted in nearly all cases, except where the catchment area is very large. Leading is better and more effective than driving; and a kindly-disposed sanitary inspector authorized to do various things at the expense of his employers gets along with residents and cleans up bad conditions where legal pressure, under drastic laws, is slow and expensive and frequently fails in the desired results. A great deal of good is accomplished by sanitary supervision of rural populations upon catchment areas from which domestic water supplies are drawn; and a considerable part of the danger that would otherwise exist because of such populations can be, and actually is, removed in this way.

3. Treatment of Sewage from Towns upon Catchment Areas.

Such treatments of sewage are carried out by or for the towns and villages upon areas tributary to the water supplies of Boston, New York, and other cities. In the case of the Boston supplies it is fortunately possible, in most instances, to take the treated sewage out of the catchment areas; and in this case the protection is more complete than it otherwise would be. In other cases this cannot be done.

It would be a happy condition if catchment areas could be always found where such sewage treatments were unnecessary; but there are many cases where this is not possible, and the best must be made of conditions as they exist. Fortunately, experience and observation extending over many years show that these matters can be managed, especially when the quantities are not too large and all other conditions are favorable, so that the risks to the water supply are greatly reduced.

4. Purification of Water by Natural Agencies.

This related especially to that which occurs when water is stored in a large reservoir. The disease-producing qualities of water, represented mainly by bacteria, are not usually long-lived; and when water is detained for months, or even for weeks, the risk of its serving as an agent of transmission is reduced. The purification of water by storage in this way has been an important element in maintaining the excellent sanitary quality of many supplies. It has its weak points, but notwithstanding them it has been one of the most useful methods in checking the spread of water-carried disease. The dangers in connection with it are, first, short-circuiting, meaning thereby the flow of polluted water through the reservoir to the point from which water is taken by a direct course and in a short time, while the bulk of the water in the reservoir remains outside the current of flow; and, second, the loss of action at the time of refilling after the reservoir has been emptied, or nearly emptied. Reservoirs are constructed primarily to maintain the volume of supply; and to serve their function fully in this respect the water must be used, and the reservoir emptied when there is occasion for it. After this happens, the reservoir is again filled with water that frequently comes in with a rush following a rain at the end of a dry period. At such times the protective action of storage is temporarily destroyed. In a few cases — such, for example, as that of the Wachusett Reservoir — the reservoir has been deliberately built larger than otherwise necessary, so that it would never be necessary to empty it, for the purpose of affording additional opportunities for purification by storage.

5. Filtration.

Without going into particulars, I shall include under this head, coagulation and all the other chemical treatments that are sometimes used in connection with it, and the basin treatments that precede it. By filtration of water, impurities are removed more or less completely. Some impurities are removed completely, others in part only. The bacteria, that must be removed to stop the disease-producing properties, are very small in size. To stop them completely requires either an exceedingly fine strainer, such as a Pasteur filter, or a sand filter of the very best construction, or else a well-adjusted chemical treatment that serves to tie up and entangle the little

bodies and make their removal in the sand easier and more complete. Looking to standards that were common some years ago, filters could be counted on to remove 95, 98, and even 99 and in some cases 99.9 per cent. of the bacteria of the applied water. The varying percentages depended in part upon the competence and adequacy of the plant and upon the skill used in its operation; and in part upon the quality of the water. Some waters are more easily treated than others, and higher bacterial efficiency is obtained from them, other conditions being equal.

In the last years there has been an undoubted tendency to cheapen filtration processes at the expense of their efficiency, and to depend in greater measure on other lines of defense.

6. Disinfection.

By this is meant the application to the water of a substance which acts as a poison to bacteria and destroys them, even when applied in such minute quantities that it is not injurious to the people who drink the water. There are other disinfectants, but at present chlorine is the only one that requires consideration. Disinfection is the most recent of the major processes of water protection now in use. It first came into use in the United States about 1906. The first disinfecting material was hypochlorite of lime. Chlorine began to be used a few years later, and proved to be better.

Under some conditions chlorine can be used so as to almost entirely kill the bacteria of the water; but there are other conditions under which the action is less complete. If the water carries organic matter, chlorine may be absorbed by it before the bacteria are reached. The dose must be carefully adjusted to cover the needs of the organic matter of the water treated and to leave a surplus sufficient to dispose of the bacteria. On the other hand, this surplus must not be so large as to be too troublesome by imparting tastes and odors to the water. If chlorine is applied to water that has not been filtered, there may be masses of organic matter which shelter bacteria in their interiors and protect them from the action of the chlorine during the short period during which there is an effective amount of chlorine in the water. Some colored river waters have been found to require very large doses of chlorine for their disinfection, and it is not impossible that the organic matter in them in a colloidal condition may sometimes play an important part in protecting bacteria from the action of the chlorine.

Having now briefly mentioned the major agencies by which water is protected or freed from disease-producing qualities we may consider their application to public water supplies.

If one line of defense is 100 per cent. perfect and can be always depended on, we might concentrate on that in a particular case. If it were fully sufficient all the other agencies might be abandoned and the water would be safe. But no one of these lines of defense is so perfect and so free

from danger of interruption and of irregularities in operation that we can afford to tie up to it to the neglect of all others.

Full safety is only secured by the use of several lines of defense. There are so many variations in conditions and in the possibilities of water supplies that generalizations may not be wisely undertaken. In each case the possibilities of protection must be considered, and lines of protection arranged to supplement each other and work together to produce a degree of protection and safety that is sufficient.

We must not go to unreasonable extremes. Human lives are valuable and must be carefully protected, but it is not to be reasonably expected that water supplies will be built that will never transmit any case of disease. To expect that is as unreasonable as to expect that railroads will be built and operated so that there will be no accidents. The underlying basis of what it is really worth while to do is much the same way in both of these cases. Risks may be estimated and values assigned to them, and the works required to eliminate and reduce these risks must not be unreasonably costly in comparison with the fair estimated values of the risks that they replace.

This may seem a cold-blooded way of considering a matter of public health; but is it not a sound, sensible way? And is it not the only way that will stand the test of final analysis? In deciding what lines of protection are to be used, and how far each is to be used, do we not have to compare the cost of applying each with the reduction in risk to human life that is eliminated by its use, and see whether it is worth while?

In discussions of the matter it may not always be wise to state the proposition bluntly. We may simply say in our reports that such and such a risk is too small to require consideration in a certain case. But this is only a general statement. If it is good for anything it must rest upon some comparison of the risk and its value with the cost of the works needed to eliminate or at least to reduce it.

As a matter of engineering, we usually have the choice of several methods of defense. To use all of them to the fullest extent would be to do more than the business warrants. It would be piling up costs against the water takers, beyond the point where all appreciable risk has been eliminated. As we do not need to use all the lines of defense to the limit, how shall the selection be made?

This will need careful study. We need to know how to select those lines of defense that will give us the desired security with the least cost and with the least disturbance to existing desirable conditions. Often the answer will be found in the application of several lines of defense. For instance, taking the first one enumerated above — it will be worth while to buy and control, as completely as ownership gives control, certain parts of the catchment area. These parts will naturally be the areas along the streams and near the intakes and above the reservoirs. They may also extend to areas which, because of topography and other conditions, are

more than unusually favorable for future occupation and pollution. The cost of the land must be considered. It will be worth while to buy large areas of cheap wild land. It will not be worth while to buy highly developed property that has been arranged to prevent pollution. A great deal of protection may be secured by ownership, even though only a fraction of the whole catchment area is acquired.

With the aid of other lines of defense, and with sanitary supervision, it may be possible to draw safe water from catchment areas on which farming, grazing, and forestry and other enterprises are conducted. The use of catchment areas for park purposes and as a recreation ground for summer visitors may also be considered. There are some extra difficulties, because occupants of this class may be harder to keep in order than permanent inhabitants. Still the advantages of such double use of mountain areas are very great; and, if other lines of defense are well developed, there is no valid reason why this should not be done.

The storage in large reservoirs often or usually helps in maintaining the safety of the supply, but it is not to be depended upon at all times. It fails to be reliable when heavy rains follow droughts that have depleted the reservoir. It has been one of the great elements in maintaining the sanitary quality of some of our supplies, even though it is not efficient at all times.

The progress that has been made in the last decades in filtration and disinfection has been so great that the idea has sometimes been expressed that with such treatments it is no longer necessary to keep up other lines of defense. It has been thought by some that it was unnecessary to purchase lands on catchment areas for protective purposes, and that it would even be possible with the filtration of the water to seal great areas of such lands previously purchased. It has been suggested by others that sanitary supervision of the population on catchment areas could be reduced or eliminated when the water was filtered. Such ideas can hardly be accepted as representing sound judgment. The protection afforded by filtration and disinfection may be made very complete; but new discoveries are constantly being made, and new points of view are reached as more is known. The importance of each new advance is apt to be exaggerated at the time. Subsequent experience often shows unexpected drawbacks. We do not even know about all of the disease-producing qualities in water well enough to be sure that all of them are eliminated with the bacteria that we count, and on which present judgments of the efficiency of the processes are mainly based.

The test of filtration by laboratory methods may seem wonderfully complete and but little short of the ideal, but actual experience through a term of years brings into play other influences that must not be forgotten. Unusual conditions when the water is more difficult to treat occur perhaps only at long intervals. There are difficulties at certain temperatures, coming each year. The purification of water at the freezing point and at

summer heat are quite different matters. Then there is the human element; success in operating depends upon unrelenting vigilance as well as upon skill. Accidents will sometimes happen to locomotive engineers; and accidents will sometimes happen to filter operators, and to the men who regulate the chlorine. These things must be given their due weight in considering the whole problem. Not an unreasonable weight, to be sure, but they must be judged in the light of broad practical experience.

As the chlorine kills nearly all the bacteria, we may logically let up on the rigidity of our filter requirements; but how much? Can we put the filter back to the point where it is only a rough strainer? Or is it not wiser to keep, even at added cost, the major part of the splendid efficiency that was obtained by the best filters before chlorine was used? And with these processes of filtration and disinfection in use is it not wise to retain to the full ordinary limit the sanitary supervision of rural populations developed before disinfection began? This is usually an inexpensive part of the protection, and it certainly produces results in the safety of the furnished water supply.

The question of the ownership of the land is a difficult one. There has been much discussion of it. Divergent views have been held and warmly advocated. Some cities, especially in the west, have been ambitious to own their entire catchment areas, and a few have come very near to realizing this ideal. In the East the difficulties of large ownership are greater, but there are few eastern cities using impounding supplies that have not made serious efforts to control at least the points of greatest danger. Looking at it broadly this has certainly been a wise policy. It may seem less necessary, now that filtration is so generally used and chlorine applied, but it is certainly in the line of safety.

Then there are the supplies — not very numerous, to be sure, but there are very important examples — where the sanitary quality reached by the lines of defense already in use has been so high that it has not been thought necessary to use chlorine. Some of us think, even in these cases, that the use of chlorine as insurance against remote contingencies would be worth while, but we must admit that results actually obtained without it leave little ground for criticism.

In these cases, with no chlorine, there is not risk of the tastes and odors that so often follow its use, and there is also a pride in having a water of so good a quality that it does not need disinfectant to improve it.

The standards of quality of public water supplies have increased, and will no doubt increase still further. When water that caused only a few deaths replaced water that caused a great many deaths, the improvement was so great that it seemed at first to be wholly satisfactory. As years go by, and our students and laboratory men study the cases minutely and find out what is happening, they sometimes find that conditions might be still better. Standards are again raised, and still better water is demanded. The art of water purification has advanced in the last decades to meet these

demands. How far it has yet to go and how the best-informed sanitarians of the future will regard the qualities of water now supplied can only be disclosed by the future. It is certain that polluted waters of years ago produced more disease and more deaths than can be accounted for by present theories of water-carried disease. When we have stopped the bacteria that are counted in the laboratory, have we stopped all the disease-producing qualities of the water? That is what we do not yet fully know, and until that question is answered more conclusively than there seems to be an immediate prospect of its being answered, we shall do well, within reason, to stick to all the approved lines of defense that are in use, and that can be economically maintained without going to unreasonable extremes.

In the meantime there is much to be done. Information is ahead of practice. There are opportunities in New England and throughout the country to secure added safety by the better application of well-known methods; and it is for us to see that no promising opportunity is lost.

Discussion.

Mr. Frank W. Green.* There are three minor lines of defense that Mr. Hazen did not touch upon, which in our case are becoming of considerable importance. These are typhoid innoculation of the inhabitants of the watershed, proper handling of typhoid patients, and the establishment of swimming pools by the cities, on or adjacent to watersheds.

Typhoid Innoculation. Every one should be immunized against typhoid fever. During the war millions of soldiers were innoculated, and the results warrant us in making it universal. The period of immunization will probably increase, as in small-pox vaccination, until those that have been caught young will require but one or two treatments to last a lifetime. In some countries typhoid fever is so infrequent of occurrence that young medical students have difficulty in finding cases for study. There is no reason why this disease of filth and carelessness cannot be banished from our country. Are we doing our whole duty in this matter?

Handling of Typhoid Patients. Doctors and nurses should be held responsible for secondary cases occurring from patients under their charge, and cases occurring on a watershed should be removed to a less hazardous locality. We heard this morning about the typhoid epidemic at Salem, Ohio, which was directly due to a single case being so carelessly handled that the entire water supply became infected. These people had undoubtedly been drinking their own sewage for years without ill effects, but as soon as unsterilized sewage from a typhoid patient entered their water supply, a very severe epidemic developed.

* Superintendent, Filtration, Montclair Water Company.

Swimming Pools. Bathing has become very popular, the last few years, and some cities have established natatoriums so that their inhabitants may have proper facilities for indulging in this most healthful sport. Others are not so decent, and the younger residents, at least, will bathe in any pool or river that they may find, irrespective of what subsequent use this water may be put to. Notices and watchmen are of little avail on a large watershed. Many will use a river for bathing even when they know that they are to drink the same water, and as a matter of fact it does not appear to affect the bacterial quality of a supply to have even large numbers of people use it for a swimming pool, so long as they are not typhoid "carriers." From an esthetic standpoint it is very undesirable to have a supply used in this manner.

Mr. A. Prescott Folwell.* There is another source of danger of typhoid, that is growing more important, and while it is not, perhaps, of direct concern to the water-works men, in a way it may directly appeal to them, — and that is what we may call "touring typhoid."

During the last two or three years a large percentage of the population of the country has taken to spending frequent vacations in touring the country in automobiles, and a great many of them, especially in the middle West and far West, spend a large percentage of their nights sleeping out rather than in hotels.

At first each person or each party camped where they could find a convenient and inviting spot, but as time passes, and quite rapidly in fact, certain spots are becoming popular, and you will find in many of them one or more camping parties almost every night during the camping season.

Now, a great many of these are absolutely in no proper condition as to either the water the parties drink or the sanitary arrangements that they make at their temporary, one-night stands. It seems to me that some control of this matter ought to be instituted. It hardly seems possible that the city authorities (or, as most of these camping places are outside of the city limits, we will say the state authorities) can take the pains to make frequent inspections of all these places. They may not be directly interested in conditions at such places, but indirectly they are, because typhoid contracted through carelessness of these people in the country is of course brought back to the city when the tourists return to their regular homes.

In the West a great many cities have established camping places within or near their borders, put up signs, and established both sanitary conveniences and cooking conveniences, places for throwing lunch boxes, banana skins, and one thing and another, and also have extended a line of small pipe from their water-supply system to furnish pure water to these campers. In that way it seems to me it may directly concern some of the water-supply people, and if they have near their cities such places frequented by campers, I wonder whether it would not be worth while, in the interest of the citizens themselves, to carry pipe lines out there and place

* Engineering Editor, "Public Works," New York.

one or two faucets for the convenience of the campers, so furnishing pure water, and not tempting them to drink water of doubtful purity, as they might get it in creeks or springs at the spot near where they camp.

Mr. X. H. Goodnough.* There has been little trouble thus far from camping, which is becoming quite common just now, so far as public water supplies are concerned. But I passed a reservoir, the other day, with a public camping ground just established across the road from it, and I think that more attention will have to be given to this subject before very long. It comes within the sanitary control of watersheds, however, and I think it is easily handled if the water-works authorities choose to take care of it. I have seen no difficulty thus far in places where there is an efficient enforcement of sanitary rules.

Mr. Stephen DeM. Gage.† The turn that this last part of the discussion has taken brings a thought to me which we have recently been discussing in Rhode Island, — the fact that automobile tourists throughout the country are passing over roads which a good many times are very close to reservoirs of public water supplies, or which pass through the watersheds, near some brook which feeds into that supply.

Our sanitary facilities throughout the country for tourists are particularly poor. There are no comfort stations except in the larger cities, and people often do not know where these are. If you go touring through the country districts, you will find many automobiles drawn up at the side of the road and the people getting out and going into the woods. Of course we can imagine what they go for. If this happens to be on the watershed of a public water supply, this constitutes a possible means of contamination of that supply. We have had in the past a number of epidemics of typhoid fever which were brought about by chance contamination of water by an individual camper, — by a fisherman, or something of that sort. Just a single instance of contamination may produce an epidemic. In order to play the game safe we must take this condition into consideration as well as some of the other conditions of which we have been speaking.

Mr. Hazen. The control of this matter is purely a question of administration. I do not know that I can give any safe general rule. Sometimes decisions rest with the city and its representatives, and they are the people most directly interested and that seems to be the ordinary natural way. At other times, as we know, state authorities determine what is to be done, and not infrequently there is more or less difference of opinion and sometimes friction when the local authorities think that the requirements of the state are unreasonable.

I do not think that any general rule can be established, nor do I think that the method of procedure affects the problem of what may reasonably be done in these matters.

* Chief Engineer, Massachusetts State Department Public Health.

† Chemist and Sanitary Engineer, Rhode Island State Board of Health.

Mr. Harrison P. Eddy.* Mr. Hazen has summarized this subject very completely, but I noticed that he did not mention one thing which is very important.

We may establish as many lines of defense as we choose, and yet there remains the item of constant vigilance, which is, after all, a fundamental thing. I will illustrate my point by experience with one case, to which possibly Mr. Hazen referred, where the sewage of the small city was diverted from and treated entirely outside of the drainage area of the water supply. It would be presumed that that line of defense was effectually established. A separate system of sewers was built, which, of course, was not intended to receive street drainage and other surface water. However, in the course of some years, connections of one kind or another were made, either accidentally or surreptitiously, so that in times of storm the main sewer became surcharged and overflowed through a manhole in a public street within a comparatively short distance of a reservoir used as a part of the water-works system. The sewage which overflowed the manhole ran over the surface of the ground down to the shore of the reservoir. That is an illustration of a lapse in a line of defense thought to have been well established, and illustrates the point that even with lines of defense, constant vigilance is required to obtain the desired results.

Mr. Albert B. Hill.† I was much gratified that Mr. Hazen gave considerable weight to long storage in large reservoirs. Those who have to do with filtration plants of various kinds have their troubles. We know that in large reservoirs the pathogenic germs cannot live very long, and that the opportunities for sedimentation and oxidation by action of winds and waves has a very important purifying effect.

There is a general feeling among laymen — the general public — that they like to have their water pure rather than reformed. If you have very large reservoirs which can be kept pretty nearly full most of the time you get the condition of large, natural lakes; but with the advantage that in the case of the large reservoirs they are generally well policed and protected, so that they soon become in the nature of large lakes of pure water. That is what the people like, rather than water that it is very necessary to treat with chemicals before it is safe to drink.

Mr. Hazen paid some attention to that. But I think that line of defense might be emphasized considerably. When we have large storage reservoirs we kill two or three birds with one stone; it is not so necessary to treat the water, — you get comparatively pure water, from the beginning, that the people like, and you get an abundance of it. These are desirable things and worth a great deal.

Mr. J. E. Garrett.‡ Is there not one line of defense which has not been mentioned? We buy land adjacent to our reservoirs and patrol it

* Of Metcalf & Eddy, Boston, Mass.

† Consulting Engineer, New Haven, Conn.

‡ Assistant Engineer, Hartford, Conn., Water Works.

very carefully, and filter the water; and after filtering the water, or chlorinating it, we then send it out to the city, and certain places may have other sources of supply connected with our system where the water is not so pure. It seems to me that that might be a very important line of defense, — that we should prohibit any connections with city water. As everybody knows, Hartford has been struggling with that problem for some time, and it seems that that is a very important line of defense.

Mr. Diven. I should like to hear the gentleman say what steps he has taken to do away with such pipe connections. It would be very interesting to any of the rest who have struggled with it, and usually with rather poor success.

Mr. Garrett. That particular question has been discussed in the engineering magazines, and probably everybody knows of Mr. Saville's ideas in regard to it, — that there should not be those connections,— and his point has been very strenuously fought by the manufacturers, but the board has adhered to its ruling but has extended the time a little again, so that the manufacturers may have time to eliminate their connections; and now we are all working together on that problem, and the manufacturers appear to have become of the mind that the connections should be eliminated, and the elimination of them is in progress now. Those connections about which there has been so much discussion are connections that were protected by double checks of an approved type. Other connections, which were not protected in that manner, have been disconnected a year and a half ago.

Mr. George F. Merrill.* This discussion brings up possibly another factor, the distribution system. Where the pipes are laid in the streets whether or not it is customary for some of the works to put service pipes and sewers in the same trench, or in the street to lay water mains very close to sewers. In my experience I found one case where a break in a sewer occurred and a break in the water pipe occurred at the same point. If the pressure had been reduced in the water pipe the sewage would have gotten into the main pipes from that source. It seems to me a pretty good idea to keep them a good distance apart.

* Superintendent, Water Works, Greenfield, Mass.

A DESCRIPTION OF THE WATER WORKS OF THE BRIDGEPORT HYDRAULIC COMPANY.

BY SAMUEL P. SENIOR.*

[September 13, 1921.]

Mr. President and Gentlemen, — In the first place, the system is practically a gravity supply. We have two emergency pumping stations, — one located at North Bridgeport and one at Fairfield.

There are four main and distinct lines of pipe coming to Bridgeport from four gravity systems. The most easterly one is what we call the Beaver Dam System.

The principal reservoir on the eastern system is Trap Falls. It has a storage capacity of 2 300 million gallons, and has an elevation of 312 ft. above mean high water.

I might say here that Bridgeport, on the whole, is located very close to high water, — between 15 and 30 ft. above high water, — so that you can see from that just about what the pressure would be.

A 30-in. pipe line comes directly into the city from Trap Falls Reservoir. It has very little drainage area of its own, but two contributory areas are piped into it by means of 30-in. and 36-in. pipe. One, Far Mill River, has a watershed of 6 square miles, and Means Brook a watershed of 7 square miles piped through a 36-in. pipe four miles long. That supplies the east side of Bridgeport, Bridgeport being divided by the Pequonnock River into the east and west sides.

The more central system is from the Island Brook gravity system. That feeds into Bridgeport through a 24-in. pipe, and Canoe Brook above it stores a 300 million gallon capacity. This is a comparatively small part of the supply. That runs in from an independent 24-in. pipe to Bridgeport.

The next towards the west is the Easton System, which includes No. 1, or Lower Easton Reservoir, and the Upper Easton Reservoir. This lower reservoir is piped direct into Bridgeport, and is fed by the No. 2 Reservoir. The lower reservoir has a watershed of about 13 square miles, and has a capacity of 200 million gallons. The upper one has a capacity of 900 million gallons. The water comes into Bridgeport through a 30-in. pipe, about three quarters of a mile of which runs through a tunnel, and is reduced near Bridgeport to a 24-in. pipe.

We have started to build a dam at this point which will impound 6 billion gallons. It will have an elevation above mean high water of 300 ft. That has been started. The plant is now set up to complete it, but owing to

* President of Bridgeport Hydraulic Company.

unfortunate conditions that prevail the work has been stopped. It was started in 1917.

The principal supply of Bridgeport comes by gravity from the Hemlocks Reservoir. This reservoir has a capacity of a little less than 4 billion gallons. It has a total watershed at the present time of 22 square miles, most of which comes from the Aspetuck River, this river being diverted by means of a low dam from its own watershed. We have planned out for the future a system whereby the Saugatuck River, west of Hemlocks, will feed into the Aspetuck and thence into Hemlocks. Our plans are made for this, the dam is designed, and the survey is all made, and much of the land has been secured. This dam will have a capacity of about ten billion gallons.

I have not said much about the Samp Mortar supply. That is an emergency supply which has to be pumped. It is on the same shed as the Easton and the Hemlocks supply. It has only a small capacity, about 200 million, and is used entirely for reserve.

About the same thing may be said of the North Bridgeport pumping station. That is located on the outskirts of Bridgeport. The pond there has a capacity of 270 million gallons, and the storage above it of 160 million from the Trumbull Reservoir and 165 million from Bunnell's Upper Reservoir.

Nathaniel Green incorporated the Bridgeport Water Company in 1853, and in 1854 built a pumping station on Bunnell's Pond and a distributing reservoir near by. In 1886 the Citizens' Water Company (a rival company) was incorporated. This company built the Easton No. 1 Reservoir at an elevation of 207 ft. above mean high water and connected it with Bridgeport by means of a 30-in. cast-iron main, an unlined tunnel and a 24-in. cast-iron main. They were enjoined from doing business, but finally joined issues with the old company and, under the name of the Bridgeport Hydraulic Company, the two were consolidated in 1888.

This company acquired the Southport Water Company in 1889 and, in 1893, the Citizens' Water Company, of Stratford. It also acquired in 1901 the stock of the Uncowa Water Company, of Fairfield. It purchased the stock of the Westport Water Company in 1916, and also that of the Shelton Water Company.

The Bridgeport Hydraulic Company now supplies water to Bridgeport, Stratford, Shelton, Trumbull. Fairfield, and Westport. The combined populations of these towns is 184 500.

The total number of service connections in Bridgeport is 23 200, and of meters, 4 700. All commercial use in Bridgeport is metered and about 1 000 domestic users. The maximum consumpton for a full year was 34.5 million gallons daily in 1918.

Due to the general depression in factories, the present consumption in Bridgeport is 24 million gallons. Based on 1920 census figures, the population supplied is 167 000. This gives a per capita consumption of 144 gal. daily.

Reservoir Table.

Reservoirs.	Capacity — Million Gallons.	Flow Line Elevation.	Drainage Area — Sq. Miles.	Water Surface Area—Acres.
(1)	(2)	(3)	(4)	(5)
Hemlocks System:				
Aspetuck Reservoir	66	225.00	17.00	60.7
Hemlocks Reservoir	3 750	225.00	5.32	437.0
Entire system	3 816		22.32	497.7
Mill River System:				
Easton No. 1 Reservoir	201	207.00	1.63	46.0
Easton No. 2 Reservoir	878	262.00	12.17	150.0
Entire system	1 079		13.80	196.0
Island Brook System:				
Canoe Brook Reservoir	293	361.20	1.60	72.0
Charcoal Pond Reservoir	12	146.00	0.18	4.1
Horse Tavern Reservoir	20	224.00	2.31	6.5
Island Brook Reservoir	300	170.85	1.61	69.0
Ox Stream Reservoir	25	198.40	0.18	15.0
Entire system	650		5.88	166.6
Trap Falls System:				
Far Mill River Reservoir	40	356.25	6.08	59.6
Means Brook Reservoir	80	345.00	5.32	19.5
Trap Falls Reservoir (Reserve)	2 300	312.00	1.16	296.0
Beaver Dam Reservoir	395	170.20	0.94	59.0
Boys Halfway River	....	....	2.50	....
Entire system	2 815		16.00	434.1
Bunnell System:				
Bunnell's Lower Reservoir	168	31.50	6.17	50.0
Bunnell's Upper Reservoir	205	165.50	4.30	63.8
Trumbull Pond Reservoir	160	180.70	13.75	52.8
Entire system	533		24.22	166.6
Samp Mortar System:				
Samp Mortar Reservoir	195	64.60	7.91	48.0

Bridgeport's water supply is collected from streams in impounding reservoirs and stored for use during the dry season. These reservoirs store, all told, 9 billion gallons, with a watershed of about 90 square miles. Most of them are high enough, 175 to 250 ft. above the city, to supply by gravity, but some are not, and to make them available there are two pumping stations which are used as a reserve. One of these is in North Bridgeport at Bunnell's Lower Reservoir, and the other is in the town of Fairfield at Samp Mortar Reservoir.

In 1917, work on a concrete dam in Easton was commenced. This dam is to be about 1 200 ft. long and 125 ft. high, and is to contain about 105 000 cu. yd. of concrete. It will impound 6 billion gallons of water. Work on this dam is entirely suspended for the present, although a very adequate and complete plant belonging to the company is installed.

It may be mentioned here that the company does its own construction work and has built five concrete dams with the same organization. It has proved to be a very flexible and economical way to handle the construction work, but this is due to the personnel of the organization. The work is conducted as nearly as may be to that of a contractor, and each working head is a man of long experience in doing similar work for contractors.

Complete surveys and plans have been made for the next development after Easton Lake is completed. This new system will be in Weston, Conn., and will be built as required. It includes a concrete dam which will impound 10 billion gallons from a watershed of 37 square miles, and a lined tunnel 6 ft. in diameter and about three fourths of a mile long. This supply, when completed, will act as a feeder to the Hemlocks dam in Easton, and will not be directly connected to the distribution system.

The company believes in buying enough land in connection with the different reservoir systems to protect the supplies indefinitely, and owns at present a little more than 13 000 acres of land. In addition to the protection afforded by long storage, the watersheds are patrolled regularly, and two outfits are kept busy during the open months, cleaning cesspools on farms more or less remote, but near enough to be possible sources of contamination. All of the water is chlorinated before being distributed, through six Wallace & Tiernan automatic outfits. A laboratory is conducted where complete chemical bacteriological and biological examinations are constantly being made by our chemists. The results obtained by these methods speak for themselves. The death rate from typhoid fever in Bridgeport for the past ten years was: 1911, 3.7; 1912, 8.1; 1913, 6.1; 1914, 3.3; 1915, 4.8; 1916, 8.6; 1917, 7.5; 1918, 4.4; 1919, 3.5; 1920, 2.1.

Two nurseries are maintained by the company, where conifers are grown from seed, to be planted on the rougher lands of the company. We are now concentrating on red pines, which, so far, have proved free from weevils, blister rust, and slugs, which play havoc with white pines at intervals. About 50 000 to 75 000 are planted on the watershed annually. Work in the nurseries is performed by men who act as overseers of near-by reservoirs, and their time is by no means wholly occupied on nursery work.

A well-equipped garage is maintained by the company, where all of the trucks and autos are housed and repaired. As materials such as coal, cement, and general supplies used on construction are hauled by our trucks, the fleet is quite extensive.

Bridgeport's distribution system includes 301.5 miles of cast-iron pipe, from 4 in. to 48 in. in diameter,—3.7 per cent. is 4-in.; 21 per cent. is 6-in.; 47 per cent. is 8-in.; 3.4 per cent. is 10-in.; 7 per cent. is 12-in.; 4.7 per cent.

is 16-in.; 6.8 per cent. is 24-in.; $3\frac{1}{2}$ per cent. is 30-in.; 1 per cent. is 36-in.; 1.7 per cent is 48-in. All pipe is purchased subject to American Water-Works Standard Specifications and is tested when made by one of the qualified testing inspectors. Practically no mains of less than 8-in. diameter are laid. The mains are laid with a cover of 4 ft.

The system has 1 767 hydrants which are owned by the city of Bridgeport but are set and repaired by the company at the city's order and expense. No hydrant rental is paid to the company by the city, although full taxes are paid. No charge for fire service is made to factories, although we require them to furnish and maintain an approved meter on each service to protect the company against misuse.

The company owns two water-front properties at the extreme easterly and westerly limits of the city. That at the easterly end is as yet undeveloped. The west end dock and yard has a dock 300 ft. long and the yard is 700 ft. deep, fronting on Bostwick Avenue. Here practically all pipe is landed and stored. Near the street, long, heavily-built platforms support gates, fittings, etc., where they can be conveniently loaded and unloaded.

A jobbing department is maintained by the company, which does most of the factory fire-service work in the city, confining its work to putting in cast-iron pipe only. Most of this work is done as subcontracts for plumbers who contract for the fire-services complete. The advantage is that, as a whole, better pipe and materials are used and better workmanship is employed than would otherwise be the case. Further than this, the company can keep and have available at all times certain men who would otherwise be laid off at times for lack of work.

In order to make use of a water power at Samp Mortar Pumping Station, an emergency station, and to keep the two men busy whose constant presence there is necessary, a feed mill is operated, where grain and corn are ground for neighboring farmers.

The company has a portable sawmill, which gets out much of the material required on construction work. Following the sawmill, choppers cut up the smaller trees and tops into cordwood, which is carted to Bridgeport and sold from two different yards as fireplace and stove wood, after being cut to required sizes by circular saw.

Discussion.

Mr. J. M. Diven.* I should like to ask Mr. Senior if the east and west sides are interconnected in any way.

Mr. Senior. Both of our systems are connected. They are balanced. It is rather a delicate thing to get them balanced. We have found times when water would back up through our Venturi's into one of the reservoirs.

Mr. Diven. You spoke of throttling the supply systems in your reservoirs, to reduce pressure. Is that by automatic valves?

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* Secretary, American Water Works Association.

Mr. Senior. No, sir; just ordinary valves.

Mr. Diven. This is the first water system that has come to my attention where the percentage of 6- and 8-in. pipes is reversed. I think the insurance man ought to be very happy when he comes to Bridgeport.

Mr. Senior. We have all along believed in using 8-in. pipe for extension work, and I was pleased to see that the Government, in the camps that they built, followed the same practice; they used 8-in. almost exclusively.

Mr. Patrick Gear.* I understand the Bridgeport Hydraulic Company is under contract with the city of Bridgeport for a certain number of years at a certain price. I should like to ask what it has done for the last couple of years, and the last couple of months, to overcome the high prices of labor and material.

Mr. Senior. We have not done anything, but I will tell you we are sweating blood.

Mr. David A. Heffernan.† How long has no hydrant rental been charged?

Mr. Senior. In 1906 we had a contract with the city whereby we were to get a hydrant rental of $12.50 a year, but there was considerable opposition to that, and we have had to forego even that charge.

Mr. Heffernan. That is very unusual for a private company. In regard to the construction work, do you use any compound in joints, such as leadite or hydrotite?

Mr. Senior. We do to a limited extent in certain instances.

Mr. Heffernan. It might be interesting to know what experience you have had with compounds.

Mr. Senior. We use lead principally, and lead wool on occasions, and have experimented some with leadite, but not very extensively, although we think well of it.

Mr. Diven. The question has been brought up of no hydrant charge. Somebody, of course, pays that. If the city does not pay it out of the general tax fund, then the consumer pays it.

Mr. Senior. Surely.

Mr. Diven. It is questionable which is the more equitable, — whether to have the water consumer pay it in proportion to the water he uses, or to have it come from the general tax fund. Coming from the general tax fund it is assessed on the valuation of the property. Under this system a man having a large warehouse and using very little water pays very little for the water supplied to him for fire protection.

Mr. Samuel E. Killam.‡ What is the average head that you deliver water under in your system?

Mr. Senior. Sixty-five to 75 pounds.

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* Superintendent, Water Works, Holyoke, Mass.

† Superintendent, Water Works, Milton, Mass.

‡ Superintendent, Metropolitan Water Works.

Mr. Killam. Then you throttle it down with the valves?

Mr. Senior. Yes.

Mr. Killam. Do the valves wear and have to be replaced?

Mr. Senior. No. The pressure evidently holds the slides up against the down-stream side.

Mr. Killam. The water is pretty free from deposits of any kind?

Mr. Senior. Yes.

Mr. Killam. Valves throttled down the way those are usually wear out, chatter in time, and give trouble. Are the large valves at the dams operated by hand.

Mr. Senior. Yes, they are hand-operated, gear gates. Some people might think it was a long operation, as it takes, on a 48-in. gate, about a half hour to open it. The only payment we get from the city in any way, shape, or form is that we get paid by meter at the rate of 3 cents a hundred cubic feet for water used in schools and fire-engine stations, and for general muncipal uses. The total amount of that is about $5 000 a year.

Mr. Thomas J. Carmody.* To what extent do the manufacturing industries install sprinklers?

Mr. Senior. They all have sprinklers.

Mr. W. C. Hawley.† It would be interesting to know what the rates for industrial and domestic consumers are, in which the cost for fire protection must be charged.

Mr. Senior. For commercial use we sell about 48 per cent. of all our water through meters, and for that we get an average price of 4.4 cents a hundred cubic feet. Our flat rate for the ordinary single dwelling is $12 a year; for a two-family house it is $22, or $11 a family.

Mr. Hawley. I don't know how you do it.

President Sherman. I doubt if there is one of us who would know how it is possible to do that without a tax levy to draw on to support it.

Mr. Senior. It comes hard. Everything is metered except domestic consumption, and domestic consumers may have a meter if they like; it is optional.

Mr. John H. Walsh.‡ In metering the large consumers, do you use compound meters?

Mr. Senior. We have a few, but not many

Mr. Walsh. Do the underwriters find any fault?

Mr. Senior. They object to the compound meter, but allow them.

Mr. Albert B. Hill.§ There are one or two points that Mr. Senior slipped over rather easily on personal matters. The first is that the company does its own construction work, and that the work is conducted, as nearly as may be, along the lines which would be followed by a contractor. The Bridgeport Hydraulic Company has gained a great deal by that.

* Water Commissioner, Holyoke, Mass.

† Chief Engineer, Pennsylvania Water Company.

‡ Superintendent, Water Works, East Hartford, Conn.

§ Consulting Engineer, New Haven, Conn.

There is another point that might be emphasized, and that is the future of this work. When the work now under way is completed, Bridgeport will be well fixed for water. They will have then something over 20 billion gallons in storage. Their consumption is, I should say, something like 10 billions, so that they will have water that can be stored for a long time, and the importance of long storage of water in reservoirs cannot be too highly emphasized, when the typhoid germ cannot live more than about two weeks in such water. The oxidizing effect of wind and wave in large reservoirs is very advantageous to the water.

Mr. Carmody. Is there any reason assigned why Bridgeport should not make the manufacturers pay for the water used in sprinklers?

Mr. Senior. There is a sentiment in Bridgeport against it, for the reason that they say that they practically do not use the water, and ought not to pay for it. It is not a proper line of reasoning. I think that the service rendered is of great value, and ought to be paid for.

Mr. Carmody. Then why does not your company compel them to pay for it?

Mr. Senior. They are more powerful than we are.

Mr. Carmody. I was going to say, Mr. Chairman, that we have that question in Holyoke now. That is, we charge the city of Holyoke $8 a hydrant a year for fire purposes, and have just notified the manufacturers that we intend to make a charge in the same manner and have them pay for the private fire protection. We believe they are using large quantities of water in opening the sprinkler heads or breaking the sprinkler valves. The manufacturers rose in a mass against it. We have not settled the question yet, but I believe that they will be compelled to pay in some way. The question is, In what way should they be charged; should we charge them for the sprinkler heads, or should we charge them for the main connection? I suggested a service charge of from $50 to $100, according to the size from 4- to 10-in. pipe.

Mr. Senior. You say you charge $8 per hydrant. That is almost the same as charging nothing, compared with the value of the service.

President Sherman. Holyoke is in the rather unusual condition of being able to get a hydrant rental from the city, with a city-owned plant. There are not very many of our municipal plants which are fortunate enough to get hydrant rentals from the city. On the other hand, so far as I know, Holyoke is practically unique in paying taxes to the city from the water department, so that to a certain extent it is a stand-off. Just how close it comes to an actual stand-off in money I am not informed. But they are not as badly off as you are here in having to pay taxes and getting nothing back.

I think there are probably no water-works men who would not say that if services are rendered by the water department, whether they include the furnishing of water or not, but what they should be paid for. It certainly is up to the water department, either privately or publicly

owned, to furnish a water supply of adequate capacity, or of suitable size, to properly take care of fire protection. There is an investment upon which fixed charges must be paid, even though no water is used, and somebody has to put up the money for those fixed charges. Now, the parties benefited by receiving the fire protection are ordinarily the ones that should pay for it, as I see it, and I think practically every water-works man takes that point of view. On the other hand, when it comes to what you can actually get, if you are a municipal department you are lucky if you get anything, and yet from Mr. Senior's experience I don't know but you are equally lucky if you get something in the case of a private company, although most private companies do get something.

Mr. Heffernan. I should like to ask in regard to the privileges given to the city departments, such as the sewerage, highway, and so forth, in using the hydrants. Do you give them full sway, or do you protect your hydrants by sending an employee of your department?

Mr. Senior. The city uses the hydrants practically as they please, but they have inspectors look after them. When we grant permission we give permits. It is done only on permit.

THE REPAIRS TO THE STANDPIPE AT BATH, ME.

BY CLARENCE E. CARTER * AND WALTER F. ABBOTT.†

[*Read September 16, 1921, by George A. Sampson.*‡]

The standpipe of the Bath Water District was built as a part of the original system of the Maine Water Company, for furnishing water to the cities of Bath and Brunswick, Me., and is located on the main pipe between these cities, on an exposed hill about one and one-half miles west of the center of Bath. The top is at elevation 247.33 ft. above sea level, or about 222 ft. above the ground at the City Hall.

The original contract for the construction of this standpipe was as follows:

Contract for Bath Standpipe, dated January 12, 1887. Between the National Water Works Syndicate of Boston, Mass., and the New England Ship Building Company, of Bath, Maine.

Structure to be located on leading main of the Bath Water Works, about 1½ miles westerly from Court House.

Mean interior diameter of about 34 ft.

Clear interior height of 74 ft.

Iron, C. L. Bailey's refined iron stamped "Central," or iron equally good. Tensile strength in every sheet of not less than 50,000 lb. per square inch of section, at any point

Lower three (3) rings not less than 9/16 in. thick.

Next three (3) rings not less than 8/16 in. thick.

Next three (3) rings not less than 6/16 in. thick.

Next three (3) rings not less than 5/16 in. thick.

Upper three (3) rings not less than 4/16 in. thick.

Bottom plates are to be 1/2 in. thick.

Manhole 11 x 15 in. clear opening.

The stone walls, filling and iron bearing bars are to be furnished in place by party of first part (National Water Works Syndicate) and the bottom plates are to be well bedded in coarse mortar by party of second part (New England Ship Building Company).

Inside to be covered with two good coats Warren's black varnish for metals.

Outside to be covered with two good coats of Prince's metallic paint.

Work to be completed on or before June 1, 1887.

Consideration, $8,200 or $8,000.

All rings are 5 ft. in height, with lapped vertical and horizontal joints; the horizontal joints on the lower side of the bottom sheet being double riveted, all other horizontal joints single riveted, and all vertical joints double riveted. The upper top of ring was reinforced by a 3-in. angle iron made up by a series of short lengths.

* Assistant Engineer, Metcalf & Eddy, Boston.
† Superintendent, Bath Water District.
‡ Of Weston & Sampson, Boston.

Standpipe at Bath, Me., after Failure due to Wind Pressure during Gale of December 14, 1917.

Looking Northwest.

Looking West.

Looking Southwest.

During a heavy gale on December 14, 1917, a section on the easterly side of the standpipe, extending down about 35 ft. from the top, failed, as shown in the accompanying illustrations, on account of the excessive wind pressure. The records of the Weather Bureau at Portland, Me., show the maximum velocity of the wind on this date to have been sixty miles per hour. The lower limit of the damaged section was at the level of the water in the standpipe at that time.

The standpipe was operated with the remaining available depth of 40 ft. until the later part of the summer of 1919 (over one and one-half years), when the Water District contracted with the Bath Iron Works, of Bath, Me., for its repair and restoration to full capacity.

For the prosecution of this work, the contractors installed at the site a portable boiler, to supply power for the steam hoists which handled the plates, and an air compressor for riveting. A staging was erected on the outside of the standpipe and a float placed on the inside.

Each plate was carefully marked, the rivets "busted" off with hand hammers, and the plate lowered to the ground. The plates were then hauled by trucks to the local plant of the contractors, re-rolled to original shape, and then replaced in the structure. In all, 27 plates were removed, 24 being re-rolled and 3 new ones furnished; those which came at the lower extremity of the damaged section being broken so that they could not be repaired.

In re-setting the plates, each ring was completed, and then the water level in the standpipe was raised sufficiently to bring the inside float to the proper working level for placing the next ring. Control of the level of the water in the tank was maintained by means of temporary telephone connections with the superintendent's office, and the superintendent in turn regulated his pumps to produce the desired result. After all of the plates had been replaced, the top of the upper ring was reinforced by a 6 x 6 x $\frac{5}{8}$ in. angle iron in 18 ft. lengths, and four steel wire guys (1 in. in diameter) were fastened to the quarter points of the top and anchored to the ledge about 100 ft. from the base of the standpipe.

As the bottom needed some attention and the paint needed renewal, the water was drawn out and about 1 ft. depth of concrete was placed over the entire bottom, and the structure was given two good coats on the inside and one on the outside of Detroit graphite paint.

The time consumed in making all repairs is divided as follows:

Repairs to the plates	43 days
Concreting the bottom	2 days
Painting	$4\frac{1}{2}$ days
Total	$49\frac{1}{2}$ days

The structure was entirely out of service during the concreting and painting only a period of six days, and during this time water was pumped

directly into the distribution system, which was protected by two relief valves, one being at the Nequasset Pumping Station, which is about $2\frac{1}{4}$ miles east of the city or $3\frac{3}{4}$ miles east of the standpipe, and the other being at the Thompson's Pumping Station, which is about 2 miles west of the standpipe.

The cost of the work was as follows:

Repairing of plates	\$5,408.81
Additional bracing and concrete bottom	1,437.82
Painting	291.63
Total	\$7 138.26

The total cost, for repairs only, is an average of \$215 per year since the construction of the tank, — the painting cost about $11\frac{1}{2}$ cents per square yard per coat, but this cost excludes some additional expense which would have been encountered had the painting been done at some other time as an entirely separate job.

The details and costs contained in this article were furnished by Mr. Walter F. Abbott, superintendent of the Bath Water District, who is a member of the New England Water Works Association.

Discussion.

Mr. I. T. Alstrom. What method is used to signal to the pumping station when the tank is overflowing? Does that ever happen?

Mr. Sampson. There is no method except to get the height by the pressure gage at the pumping station, and that is affected by the draft in the city so much that it is unreliable. The water company owns the hill, and, as there are no houses within, I should judge, a quarter of a mile of the tank, there is no danger from overflowing.

Mr. Alstrom. In our town we only own a few hundred feet around our tank, which has been overflowing so that the man who owns the land near the tank has been threatening to bring suit against the town for washing his land. We have just established an electrical system whereby a horn is blown in our pumping station until the engine is shut off and the water gets down to the regular level, which is 2 ft. from the top of the tank.

President Sherman. Some sort of telltale at the pumping station is almost essential to a proper operation of the standpipe, of course, but a great many water-works systems are still getting along with such information as they can get from their pressure gages, and taking chances otherwise.

THE CONTROL OF WATER WASTE BY HOUSE-TO-HOUSE INSPECTION.

BY GORDON Z. SMITH.*

The Bridgeport Hydraulic Company serves water to the city of Bridgeport, towns of Stratford and Fairfield, the boroughs of Nichols Farms and Long Hill.

The estimated population served, based upon the census of 1920, is 167 000.

There are 23 194 service connections, on which there are 4 673 meters, classed as follows: 2 780 commercial, 1 763 domestic, and 30 test meters. There are 22 500 customers' accounts for water billing.

The inspection service is intimately connected to the water charge accounting, for it is the basis for all charges except, of course, meter accounts. The inspector enumerates upon a blank the water fixtures upon any service, number of families, stores and shops, and whatever the character of the use. The charges therefor are entered upon the slip, totaled and transferred to the ledger card bearing the same account number as the completed inspection blank. As changes occur, either addition or disconnection of fixtures, a new inspection slip is filed in place of the old one, and the proper entries made upon the ledger card. Notice of the additional charges are then sent to the owner. Vacancy claims, disconnections, additions and new buildings are all verified and reported by the inspector. Inspectors are chosen for their fitness and adaptability in their work. Courtesy being the foundation of our relation with the public, we insist upon it first and last, with the result that there are very few complaints made at the office.

As a secondary but an important feature of the inspection service is the leak detection. The inspector reports all leaking fixtures and pipes, and sends notice to the owner requesting repairs be made. This request is followed by a reinspection to ascertain if repairs have been made. If not made within a reasonable time, a special letter is sent to the owner stating that if repairs are not made within a specified time a meter will be set because of the leak. That is also followed up, and if not repaired the owner is notified that a meter will be set.

Two or more years ago it was necessary to set many meters for the above reason, but at present repairs are made with considerable dispatch.

Premises in which leaks are found upon every inspection, but repaired after repeated notices, are selected, and the owner is notified to keep such

* Chief Inspector, Bridgeport Hydraulic Company.

premises free from leaks or a meter will be set, and if leaks are found after such notice a meter is installed after due notice to the owner.

Many underground service leaks — leaks which do not appear on the surface — are found by our inspectors by shutting off the house supply in the cellar and listening to the pipe with a water-phone.

During the extreme cold weather the inspectors make special inspections of premises in which the pipes and fixtures are known to be in an exposed location, and if found to be running to prevent freezing a special letter is mailed to the owner with a warning that the practice must cease, and if found a second time a meter will be set forthwith. This is also checked by a reinspection, and if found running a second time, a meter is set.

The inspection force is large enough to cover unmetered service twice a year, together with all other reinspections and miscellaneous work. This requires a total of nearly 60 000 reports from five or six inspectors.

General Results.

While we realize that a 100 per cent. metered system has many advantages, there are also disadvantages. It is not within the purpose of the author to discuss that in general application; however, it may be said that metered service is the fairest method of selling water, and we may all come to it as a last resort.

The attitude taken by the Bridgeport Hydraulic Company toward this subject is governed by the peculiar conditions, and in some instances universal conditions, to be met in our customers. The supply at present and since 1918 has been by gravity from a long-time storage, with treated water. The highest daily average for one year was 1918, when it reached 34 000 000 gal., 47 per cent. of which was charged by meter. The highest daily average for one month, that year, was in January, with 41 000 000 gal. Some days the rate exceeded 44 000 000 gal. In 1919 the daily average was 29 000 000 gal., of which 49.6 per cent. was metered to the consumer. In 1920, the daily average rose to nearly 32 000 000 gal., of which 50 per cent. was metered. For the seven months of the current year the average daily consumption was 24 000 000 gal., of which 47.8 per cent. was metered. The above records are from Venturi meters and service meters. It will be noted that with about 20 per cent. of our services metered we actually account for and charge for 47.8 per cent. of our water by meter rate. In 1920 our meter billing charges were nearly equal to the flat rate charges.

It can be said that in some cities, with every tap metered, only 50 per cent. of water can be accounted for. According to the State Board of Health of Massachusetts, 1900, no city of the state having over 90 per cent. of the taps metered accounts for over 62 per cent. of the water furnished.

Therefore it would appear that our meters are being placed where they are most effective, also that our per-capita consumption is high, but not excessively high after all the proper allowances are made for losses that

would not appear upon the service meters. The per-capita daily consumption for this year to July 31 is 144 gal. No floating or transient population was estimated. Deducting the metered use leaves a balance of 75 gal. for flushing, fire protection, underground leakage from 300 miles of mains and 23 000 services, does not leave such a large amount for unmetered domestic use and for leaks from household pipes and fixtures.

Mr. Dexter Brackett, 1895, stated that it is not practicable to reduce waste below 15 gal. per capita in large cities, and that this figure can be reached only by universal use of meters.

Just what the domestic allowance should be for our system is undetermined, but by assuming a fair figure, say 50 gal., we shall have something reasonable as a working basis.

It may be said that the above is large, but the conditions are a bit different here than the average city. The people have always been told that there would be an abundance of water for their use, and it is believed that they use it accordingly.

If, as stated above, 15 gal. is allowed as waste which meters would not eliminate and 50 gal. as a fair allowance for domestic use, we have a remainder of 10 gal. per capita per day for the meters to save for us, which is 1 670 000 gal., which for one year amounts to 609 000 000 gal. If capitalized at $58 per million, which is our average rate for metered water at present, equals $35 000 revenue from estimated waste of water. Let us now check the cost of saving this amount against the cost of meters and the public sentiment against meters.

We will require 19 000 meters installed at a cost of $22 per meter, which would amount to $418 000 at 6 per cent., equals $25 000 interest charge. Four per cent. for depreciation and retirement charge equals $16 720. Cost of reading meters, repairs, and accounting might easily reach $19 000. This totals $60 720 as a fixed charge per annum against meters. Therefore we may say that our income might be increased $35 300 per annum by spending $60 720.

There is the almost universal opposition to meters upon domestic supplies for many reasons which demand recognition.

It would appear to us, therefore, that with the power to install meters where the use is large and of a nature to be beyond control or unreasonable domestic use and for waste after notice to repair, we effect an excellent working balance by controlling the house fixture leakage through inspection and insisting on prompt repairs. By this method a large percentage of our consumers have the use of water for domestic purposes without a thought that every drop used is measured. It enables our Company to operate on a very liberal basis so far as the domestic consumer is concerned, and our experience has been that a great majority of water-takers appreciate the situation and do not wilfully waste the water. We have been able, by close coöperation with users, to feel that the public is educated in belief

that this company is living up to a very liberal interpretation of its charter obligations to give the community a wholesome quantity of pure water at a reasonable charge.

Discussion.

President Sherman. We have heard a great deal, in recent years, in favor of 100 per cent. metering. This is the first time we have had a real presentation of the other side of the case for a long time, if ever, in this Association. The paper is before you for discussion.

Mr. Carleton E. Davis.* I notice that you deal with the owner of the property. Does the owner ever blame the tenant for wasting water; and if so, how do you handle that situation?

Mr. Smith. We have a great many of these complaints, naturally, because Bridgeport is a city containing a good many tenants; but the owner is the man who pays the water bill, and we have to look to him for the responsibility. If he can't keep his tenants responsible to him, certainly the tenants would have no dealings with us.

Mr. J. M. Diven.† High economy in the use of water is probably less important in Bridgeport than in places where the water has to be pumped, maybe pumped, filtered and again pumped. A gravity supply with ample water does not stimulate water-waste prevention as more difficult and expensive supplies do. The speaker's experience is that house-to-house inspections do cause friction, as some people seriously object to having the inspectors go through their houses to look for leaky fixtures; they consider it as much an invasion of personal rights as a search for hooch.

The writer spoke of the reasonableness of notifying property owners before setting a meter; the speaker thoroughly agrees with him in that. The speaker's practice has been not only to notify them before setting a meter but also to put the meter in on trial for a month, then have a reading taken and the result, with a statement of the cost by meter measurement, sent to the owner, and a notice that the meter rate would commence a month from the date of the first reading, thus giving a month to repair leaking fixtures or install better ones before the meter charge began. In some instances meters are set without even the knowledge of the property owner, his first knowledge of the fact being the receipt of a large water bill, which is a manifest injustice.

Mr. Smith. There is almost no friction at all here among the occupants of houses in letting the inspector in to inspect the water pipes and fixtures. The system has been in operation here for some time, and people expect the inspector twice a year. If there are leaks in the house which the landlord doesn't repair, they like to have the inspector come around. We

* Chief, Bureau of Water, Philadelphia, Pa.

† Secretary, American Water Works Association.

have a good many reports from tenement houses where there are leaking water fixtures, — "Please send up an inspector and get the landlord to repair it."

MAJOR ROBERT C. WHEELER.* On the question of metering generally, when I first took charge as manager of the water company at Chester, Pa., I found that the water accounted for was something around 72 or 73 per cent. of that which was pumped. Now, the first thing I did was to improve the facilities for testing the meters, and that campaign proved very much worth while, because we increased the water accounted for to about 80 per cent. That is, we were able to collect for 10 per cent. more water than we had done.

We were not as fortunate as Bridgeport, because we had to pump and filter all the water, and our lowest rate was something like 10 cents a thousand gallons, so that the increase in revenue was considerable. One reason why some people are disappointed in their experience with meters probably is that they do not test them frequently enough and do not keep them in such a state of repair that they register as they should.

MR. W. C. HAWLEY.† Replying to the question which Mr. Davis asked, it seems to me that the owner is the man who is responsible for the character of the tenant, and that he, therefore, has the responsibility for the water bills, — at least, to a certain extent. Our company goes on the principle that it will deal only with the owner. He can protect himself by occasional readings of the meter, and by proper maintenance of his plumbing, so that there should not be any serious difficulty there.

I believe under the conditions which Mr. Smith has outlined that he is perfectly justified in not metering a large proportion of his consumers. A study which I assisted in making a few years ago, of a city in central Pennsylvania, showed that where they had an abundance of water and their flat rates were already low, it would have been very difficult to introduce a meter system. It probably was not necessary. But the day is coming, when they approach the limit of their water supply, when they will be forced to meter, and I believe Mr. Smith is gradually approaching a 100 per cent. metered condition. My experience has been that the objection to meters on the part of the consumers is a matter of education, and that within a short time after the meters have been installed there is just as much sentiment in favor of the meters as there was previously against them. With the pressures that you have here in Bridgeport I see no reason why a larger percentage of water should not be accounted for. In our own case, with pressures in our distribution system ranging over a large proportion of it, from 125 to 160 lb. and in parts of it at more than 200 lb. to the square inch, we account for 75 per cent., and in some years we have accounted for something over 82 per cent. Of course we are 100 per cent. metered. But in making that estimate we have not allowed anything for

* Of Horton, Barker & Wheeler, Engineers, Albany, N. Y.
† Chief Engineer, Pennsylvania Water Company.

water used for fire or street purposes, or leaks, or any other use than water actually measured.

Mr. F. A. McInnes.* We were forced, in Boston, under state law, to meter all new services and 5 per cent. of existing services each year, beginning 1908. We anticipated all kinds of trouble which has not materialized; in fact, as far as the consumer is concerned, our difficulties have been practically negligible. The installation of meters began in Charlestown and East Boston, at the northerly end of the city, and the work is progressing southerly through the city. The trouble is to keep within the designated section, as hardly a week passes that we are not asked to set meters outside of the area in which the work is being done. Mr. Hawley has expressed it exactly when he said that when the people know they are going to have meters they soon become educated to them.

We started in 1908 with 5.7 per cent. of our services metered, a daily average consumption of approximately 98.4 million gal., a per capita of 158 gal. and a population of approximately 623 000 — I am using the old census, Mr. Killam. Eight years later, with 53.2 per cent. of services metered, we were using 77.6 mil. gal. of water with approximately 126 000 more people, a per capita of 104, and a reduction in the total daily average amount of water delivered into the city of about 21 000 000 gallons.

During the years 1917–1918 the installation of meters was suspended by special enactment of the legislature. The work is now again in progress.

Ours was a case of must. We had to spend money to put meters on every service or face a very large expense for our portion of the cost of extending the works of supply.

I do not consider house-to-house inspection a success, in a large city at least. It is not sufficiently enduring and does not stop very serious cases of waste, such as faucets being left open carelessly, for cooling purposes, etc.

It has been our experience that those who use water without stint, and don't waste it, find their bills satisfactory. The few who waste water carelessly have been paying out more money than they did before.

Mr. Smith. I want to correct one statement. In my paper I made no estimate of water that we account for; but if we were 100 per cent. metered it was assumed we ought to account for 100 per cent.

We receive pay for 50 per cent. of our consumption by meter charges, in addition to what we sell on flat rates.

Mr. H. V. Macksey.† It looks as though the present speaker had made a good case for his own city and his own company.

It was some years ago that I had something to do with the meter system, so-called, of Boston. One of the reasons why the people despised the meter, and hated the meter inspector in Boston at that time, was because the meters were not practicable, durable, fair-measuring machines.

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* Division Engineer, Boston Water Department.

† Superintendent, Public Works, Framingham, Mass.

The city was full of meters that should have been scrapped. Boston would never be metered to-day were it not for the fact that they are buying water by meter and that the statute compelled them to sell by meter. They are now doing good work, and, as far as I can gather, the people of Boston are not dissatisfied.

Since that time I have had something to do with the water works of two small towns or cities. In the first one, when I went there, a fund was provided to purchase meters and put them in service when water takers should ask for them. A few of the water takers knew a thing or two and asked for meters, as the rates were so arranged that they would save money. Others thought the meters were no benefit and didn't want to be bothered with them. The Board of Public Works couldn't agree upon whose meter to buy, so that the fund lay there for several years and people got no meters. When I took charge of the system I pointed out to some of the people that they better ask for meters, and we soon used all that money and had to apply for more meters. That was because our rates were arranged so that they gave an advantage to the man who was economical and saving.

Now, it may be possible that in the city of Bridgeport, by inspecting twice a year, you can keep down leaky fixtures; if so I think you have pretty nearly reached the miraculous, because with ordinary plumbing if the average ball cock runs for a year without leaking it does very well. When you find small leaks that seem trifling but which you ought to stop because you know they are going to become larger day by day, the owner objects to incurring great expense for a little water, and the plumber will say that it doesn't amount to anything. Now, if you are a private corporation and deal with the owner, you can shut the water off.

If the works are owned by the municipality, it is different, because you will find a man who sits in judgment in the matter of water rates, but he is likely to be a supplicant a short time before the next election, and so he wants to be not only fair but generous in some cases, and you can't blame him. And if you have, as we have in the town that I am now in, a law that compels you to furnish water to any man who asks for it, he makes his initial payment, whether he be an owner or a tenant, you then have another complication. We have many cases where the tenant wastes the water, has a big bill, refuses to pay, and we shut off the water. The Board of Health then tells us that it is a matter of health and we must supply the water. They do not tell us anything about who is to pay the bill. The tenant then starts anew, makes the initial payment, and everything goes along very finely until he wastes some more water and then refuses to pay. Of course you have a claim against him, but these small water bills are not collectible in court, as they are too trifling, and where the money is owed to the municipality your chance of collection is very small. There are many reasons why a meter service is to be preferred in a municipally operated plant where it would not be in one that is operated by a private corporation.

There is one thing that we all must consider, which was touched upon by Mr. Hawley. In a great many water systems we are approaching the limit of our supply. It is not a matter of money alone; it is a matter of safety and of large expenditure later on. In the departments that I have had anything to do with, I have always tried to enforce a rule that no man may waste water, even though he pays for it.

I am very much interested in the success of the plan as carried on in Bridgeport, but have my doubts as to whether it could be successfully applied in the various cities and towns that I have been in touch with in Massachusetts.

MR. ALBERT B. HILL.* In the case of Bridgeport, as indicated by Mr. Smith, it seems to be at the present time more economical to sell water at the flat rate, because there is plenty of water and a gravity supply; but when the time comes that they get about to the limit of that supply and additional water must be supplied at great cost, then conditions will be different. It will be found that the average property owner, if he has a metered system and his attention is called, by the bills or by the inspector, to the fact that he is wasting water, will give prompt attention to making repairs. On the other hand, if he pays on a flat-rate system and his bills are just the same whether he wastes a lot of water or whether he does not waste any, he is likely to give very little attention to the matter.

Metering will enable large expenditures for additional supplies to be postponed.

MR. WALTER P. SCHWABE.† We have heard from the large companies principally, and I might relate the experience of a medium-sized company in Thompsonville, Conn. In 1915 the entire system was metered, about 1 800 meters being installed. The city is supplied by springs that have a yield of approximately a million gallons a day, and that supply seems to be very regular the year around. Previous to that time, during the summer, and sometimes in cold weather in the winter, the demand would exceed that million gallons a little, and the storage supply would be cut down so that the company would notify the consumers to stop the waste of water, or to stop the sprinkling of lawns and the sprinkling of streets. As a matter of fact, they bought a gasolene pump to fill the water carts from a creek in 1914.

Since 1915 we have been encouraging the use of water. During the war I advertised how much better their gardens would grow if they would put water on them, and we sold this water at 50 per cent. of the regular price for water, to encourage the use of it. We cut down the daily consumption perhaps between 30 and 40 per cent. There was considerable opposition to the installation of meters. After a year with meters our records showed that 70 per cent. of the residence consumers were paying less for water than they did on the flat rates. To-day you could not change

* Consulting Engineer, New Haven, Conn.

† President, Thompsonville, Conn., Water Company.

them back. This system has been very beneficial to the consumers as well as to the company.

On the other hand, another small system that I operate is a gravity system, and it is impossible to figure the proposition of metering. We have plenty of water, and I do not see how we could earn anything additional to compensate for the investment and upkeep of the meters. The operating expense would be materially increased in this little plant if the services were metered — approximately 500. I do not see any way of getting any additional revenue. It is not necessary to meter, because there is a sufficient supply of water. It is evident that the question of metering or not metering depends on the local conditions.

Mr. William A. Mackenzie.* The place I represent, Wallingford, Conn., has 1 700 taps, about 18 per cent. of the services are metered, from which we derive about 40 per cent. of the total revenue. It is a municipal company and we permit meters to be installed on house services upon application and also set meters where necessary to prevent or stop leaks.

It seems to me, whether it is a private or municipal water company, — although in our case we have a large surplus of water, which makes it more advisable to slowly come to the metered system,—that the meter rate is the more equitable and will eventually be the method of collecting most water rents.

In private companies it is very necessary and also with municipal companies, to avoid troubles and disputes with the consumers, for the best of relations and coöperation must be maintained. It is the best plan to increase the number of meters gradually, and thereby prevent the troubles that are bound to come if we attempt a 100 per cent. metered system at once, or when there is an abnormal growth and excessive use of water beyond the capacity of the plant.

Mr. Allen Hazen.† A few years ago the president of a water company told me of his experiences. He was serving a ground water supply of excellent quality but of limited quantity, to a growing community, and he had made up his mind that the only way that he could continue to meet conditions was to adopt meters. His takers were opposed to the meter system, but he knew something of human nature and of the people he had to deal with. He announced publicly and emphatically that he did not believe in meters and he instructed his superintendent not to set any more of them. The people soon became excited, and there were some arguments to which he finally yielded as gracefully as he could. Fifty-one per cent. of his services are metered to-day, and the rest are following.

Mr. Lincoln Van Gilder.‡ In our town there is about 65 gal. per capita consumption on the actual population, — not the summer population. In a neighboring town they are using about 200 gal. per capita, and they

* City Engineer and Superintendent, Water Works, Wallingford, Conn.

† Consulting Engineer, New York.

‡ Superintendent, Water Works, Atlantic City, N. J.

are very hard put to it for money to keep going. They are in a quandary whether to spend $40 000 by increasing their pumping and filter beds, which takes no account whatever of other expenses in connection with the increased supply. It is a question of the strength of the gridiron system to carry the water to them.

I should like to ask Mr. Smith if in making up his tabulation he figured out what it cost them to make their house-to-house inspection, per annum.

Mr. Smith. I think, about $11 000.

Mr. Diven. In this town you speak of as using so much more water than you, they may have more manufacturers.

Mr. Van Gilder. They have not any more manufacturers than we have. They have two glass manufacturers there, which are not very heavy users of water.

Mr. Diven. Then you have the ocean to bathe in.

Mr. Van Gilder. It may be interesting to know that the days on which we have the heaviest bathing in the ocean we have the heaviest pumping, because every bath means a shower bath and the washing out of the bathing suits.

Mr. Hawley. Mr. Van Gilder's statement of 65 gal. per capita is very interesting to me. I remember in 1896, when I took hold of that plant, the per capita consumption was from 250 to 260 gal. We began by making a house-to-house inspection — which, by the way, increased considerably our flat-rate revenue by finding hundreds of fixtures which had been put in but not reported by the plumbers, — and where we found leaks we told them that if the leaks were not stopped a meter would be set. That was more effective than a threat to shut off the water. We succeeded in getting through the following summer without the water shortage which had been encountered during the two previous seasons, and within two years the per capita consumption was down to between 50 and 60 gal.

I am reminded by what the last speaker said that there are cases where water is used, where spigots and so forth are permitted to run, that inspection will not catch. I have in mind where a house with a $5 minimum rate had a $30 bill for six months, and the inspection showed that the woman who lived in the house had an idea that to permit the hopper water closet to run a couple of hours every morning was a proper and sanitary thing to do. That is where the water had gone. The inspector might have caught it or he might not.

I do not see why there should be the objection to meters that there apparently is in some places. A meter places the burden where it belongs. If a man does not use much water there is no reason why he should pay for what someone else uses, and if he uses a great deal of it he should pay for it. It is the only just method of distributing the burden.

Mr. Davis. Touching on the tenant and landlord question once more, if the real object is to save water irrespective of collecting revenue for all the water used, I believe there must be some responsibility upon both tenant

and landlord, for paying for water used. I know of a case where a certain tenant has wasted water in order to run up a bill on the landlord so that the landlord would be willing to sell at a reduced figure to the tenant. In these days, particularly of late, I think the tenant out of spite frequently does use considerable extra water.

If we are determined to stop water waste irrespective of who pays for it, I think something must be done to place some responsibility upon tenants.

Mr. Hawley. We take care of that situation to a certain extent by offering to the owner, if he does not care to read his meter, to make a monthly reading of that meter for a normal fee and report to him by post-card, so that he has tabs on the amount of water that is being used, and, at any rate, he knows within thirty days if there is any considerable increase in the amount used and has an opportunity to protect himself.

Major Wheeler. My experience along that line seems to indicate that it is difficult, although it is not impossible, to make the owner responsible for the water bill. In a very small number of cases, in dealing directly with the tenant, has there been money lost through the failure of the tenant to pay before he moved, or for some other reason, and the amount has been very slight. We always have had a good deal of trouble with the landlord, who said that he was under a contractual relation with his tenant through the lease and he had no way of really controlling how much those water bills should be.

Mr. Michael F. Collins.* Speaking about tenants and water meters, I think there is another class of people that we have to consider, too, and that is the manufacturers. A good many of them we would never accuse of anything wrong. But I have one factory in whose neighborhood every Saturday afternoon and Sunday I had numerous complaints about rusty water. I consulted the master mechanic of the establishment and asked him if he knew any cause for it, and he said, no, he did not use any water to cause it. Finally it got so bad I went to him and said we would have to put a meter on. It happened to be a 10-in. service. We made installation, and I want to tell you, gentlemen, now, what I think will surprise you: The first full quarter we got $750 out of a concern that never had used any of our water before.

So I think, as far as the meters are concerned, they are most justifiable, and every service ought to be metered, both in justice to the city or company and the consumers.

Mr. Van Gilder. In regard to the responsibility as between the landlord and tenant for the water bills, it is very frequently done in our town, when the leases are drawn, — to have the landlord held responsible for the minimum rate and the tenant to pay the excess. I do not recall a single case where there has been serious difficulty in collecting on that basis.

* Superintendent, Water Works, Lawrence, Mass.

We collect from the owner, of course, and he in turn goes back to the tenant.

PRESIDENT SHERMAN. It seems to me that Mr. Van Gilder has a method that should be followed much more commonly, and one of which our real estate men might take some cognizance, especially with the increasing friction which may result between the landlord and tenant on meter bills.

For instance, I have personally recommended, in cases that have come to my attention, that leases be drawn providing that the tenants shall assume the water rates. But that has nothing to do with the method of billing, which, in almost every case with which I have come in contact, has been to the owner. It is merely a matter of who shall make the payment. The owner receives the water bill and turns it over to the tenant. If the tenant does not pay the bill the water is shut off. Of course if the tenant leaves with an unpaid bill the department collects from the owner. But, taking it by and large, that method works out the best of any that I have known of being tried. It is not customary among real estate men to draw leases in that way, but I can see no reason why they should not do so.

MR. HAWLEY. We go a step further. We deal with the owner, but when the owner says, "I want the bill to go to the tenant," we send the bill to the owner in care of the tenant, and it is up to the tenant to pay the bill, though the ultimate responsibility is still with the owner. In our district nearly all leases specify that the owner shall pay the minimum rate and the tenant shall pay any excess. This, of course cannot apply to apartment houses.

MR. M. N. BAKER.* There is one question which it seems to me enters into the question as to whether it would pay to install meters in Bridgeport, which I think has been left out of the account. That is, if this water were saved, the date for getting more water would be postponed. I think some credit should be allowed on that account. In going over the water-works system yesterday I saw a big cableway where I was told that they were just waiting time before they put up a 150-ft. dam to impound more water. If the date of building that and other impounding reservoirs were to be postponed, by the installation of meters, certainly something ought to be credited to meters on that account.

MR. HAZEN. Although a digression, I think another matter relative to meters appropriate at this time. Some years ago this Association had a committee on meter rates, and, after a long deliberation and much discussion by the Association, the Association adopted a form of meter rate in which the quantities of water under the successive steps of the schedule were standardized; and that meter rate adopted by this Association, I am happy to say, has been adopted in a great many cities, supplying hundreds of thousands of services with water, and I have recently been writing to the places where it has been used, as far as I knew of them, and asking for the

* Associate Editor, *Engineering News-Record.*

results, and they have usually been very satisfactory, — they have gotten along with comparatively little friction.

At the meeting of the American Water Works Association in Cleveland, a committee was appointed to standardize the steps of the meter schedule, and that committee now has the matter under consideration. We remembered the work of this Association of several years ago, when standard steps were adopted, together with a standard form of meter rate. The adoption of that standard rate by this Association, has, I believe, been most helpful to the water-works business throughout the United States. The adoption of a similar standard by the American Water Works Association would be even more useful. But we do not wish to have any competing schedule set up by it. Since the schedule was adopted by this Association some years have passed, and meter rates in the adopted form have been used and experience gained with them. No doubt various points of view will be presented to the present committee, but I think the disposition of all members of the committee will be to take the New England form as a starting-point, and to modify it as little as may be. Our committee thinks that it would aid if this Association, and perhaps other water-works associations, would each appoint some one to represent it in this matter, with a view to getting every one to agree to any changes that may be desirable and to have one standard adopted for the whole country. I hope we shall have the coöperation of this Association in this important matter.

Mr. Hazen moved that the President designate some one to coöperate with the committee of the American Water Works Association, which was voted. The President appointed Mr. Arthur E. Blackmer.

THE TYPHOID FEVER EPIDEMIC AT SALEM, OHIO.

BY W. H. DITTOE.*

[*Read September 15, 1921, by* MORRIS KNOWLES.†]

The epidemic of typhoid fever which occurred at Salem, Ohio, during the fall of 1920 is of unusual interest to persons engaged in public health work. This epidemic showed one of the highest case rates ever recorded, and at the same time the mortality rate was the lowest of the important epidemics of the United States. The epidemic was caused through the medium of a public water supply which for many years had been of a high degree of purity and had never previously been held responsible for any water-borne disease.

These features of the epidemic warrant a complete relation of the circumstances surrounding it, and there is now in preparation an official report, to be issued by the State Department of Health, which will supply all details. Therefore I shall not endeavor to discuss completely all phases of this epidemic, and shall only relate the important circumstances, including a description of the water-supply system and the manner in which it became contaminated.

The city of Salem is located in Columbiana County in the northeasterly portion of Ohio, at the headquarters of Little Beaver River, a tributary of the Ohio River. The population of this city is about 10 000. It has a thriving industrial development, but its rate of growth has been rather slow. In addition to its public water-supply system the city has a system of sewerage constructed on the separate plan, and also has a number of paved streets. The sanitary sewers cover practically all of the built-up area, and serve a population of about 9 000. Sewage is delivered to a sewage-treatment plant located northwest of the city, consisting of tanks and intermittent sand filters, the effluent from which is discharged into a small creek. This plant is inadequate, and, moreover, it has been greatly overburdened, due to the misuse of the sanitary sewers. The city has neglected to control sewer connections, and as a result these connections have been established very carelessly and have permitted large volumes of surface and subsoil drainage to reach the sewers. In addition, there are several poorly constructed private sewers connected to the system. It will be shown later that the improper control of sewerage was a contributing cause to the occurrence of the epidemic.

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†Consulting Engineer, Pittsburg, Pa.

History of Epidemic.

During the early part of September, 1920, an outbreak of enteritis occurred in Salem, and was observed by the local physicians and the health commissioner. This outbreak was not intense, and as cases of intestinal disorders were more or less prevalent in other communities nearby no particular concern was aroused. It was thought by local physicians and health officials that the sickness was "intestinal influenza," but in the light of facts later learned the Salem cases were without doubt of a different kind and due to an entirely different cause. After partial subsidence of this outbreak, a second and much more intense outbreak of enteritis occurred, starting about September 23 and consisting of approximately 7 000 cases. Typhoid fever made its appearance about October 1, and after October 12 the typhoid fever cases increased very rapidly, the epidemic mounting to a peak on November 1. Thereafter, a rapid decline occurred. The total number of typhoid fever cases which were reported and investigated was 884, including not only the epidemic cases but those which preceded and followed the epidemic, a period of two months. The total number of deaths resulting from the epidemic was 27. Chart No. 1 illustrates graphically the course of the epidemic.

While investigations showed that the typhoid fever epidemic started about October 1, the actual existence of typhoid fever within the community was not known until October 13. In the early part of October the city health commissioner issued a public warning that the water from the public water supply should be boiled, but this warning was only based upon a policy of playing safe, and was not the result of knowledge that the water was contaminated. In fact, at that time the water supply of the city was still considered to be above suspicion owing to its previous history. The State Department of Health was called upon October 13, 1920, to investigate the enteritis outbreak, and in connection with this investigation, which was conducted by an epidemiologist of the department, the existence of a few cases of typhoid fever in the city was learned. Circumstantial evidence pointed to the public water supply as the cause for the enteritis, and accordingly a boiling notice was repeated on October 15, and request was made by the epidemiologist for an engineering investigation of the water-supply system. This was conducted as promptly as possible, and included field analyses of water samples. The results of this study are shown graphically by Plate No. II. The result of this investigation fixed the water supply conclusively as the cause of the epidemic, and accordingly disinfection of the water supply with liquid chlorine was decided upon and started October 20. It is pertinent to observe that at this time the local health department knew of only four cases of typhoid fever in the city, but as the subsequent studies demonstrated, about 100 persons were suffering from the disease at the time whose cases had either not been diagnosed or had not been reported. The disinfection of the public water supply checked the epidemic. It of course

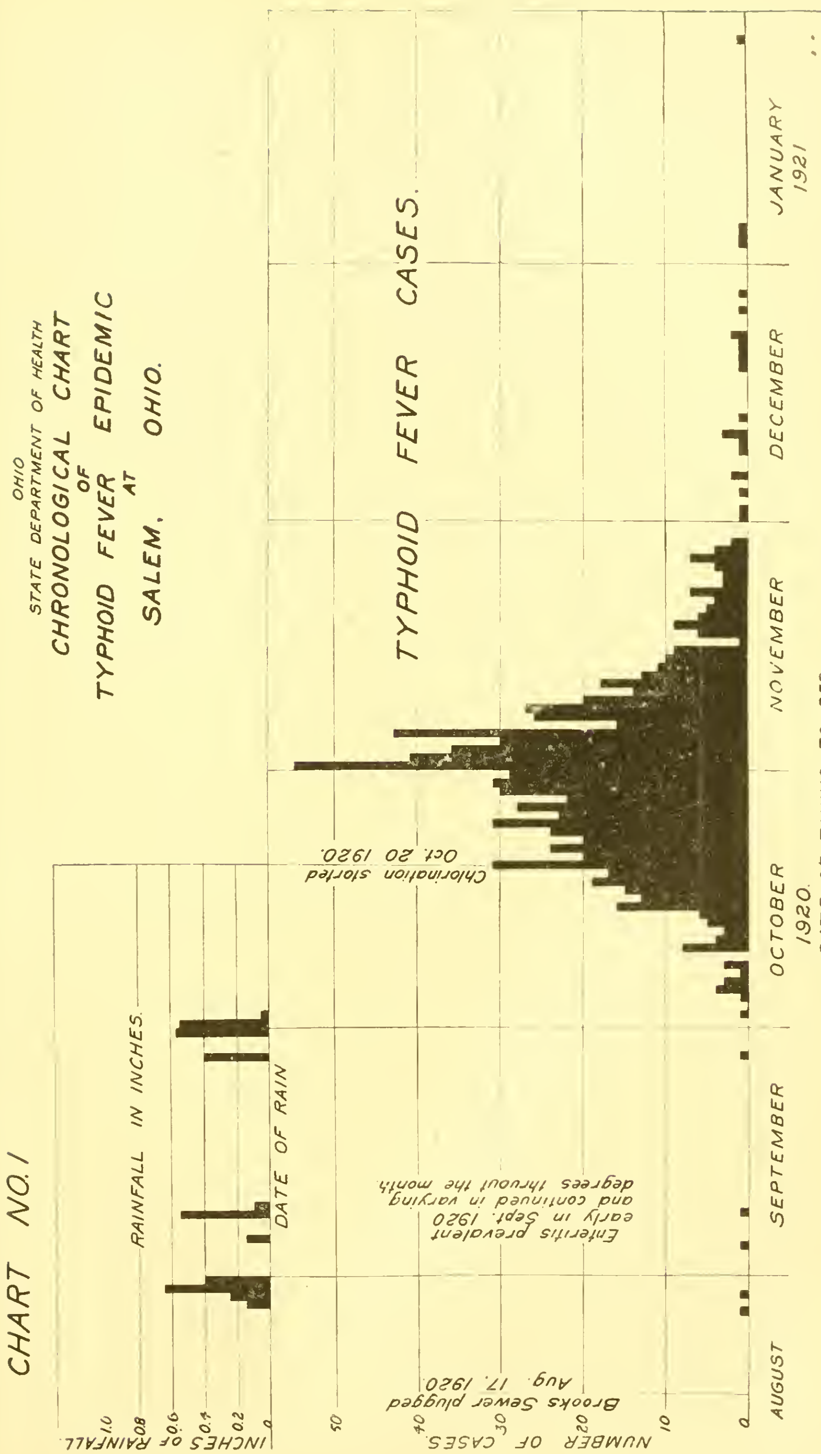
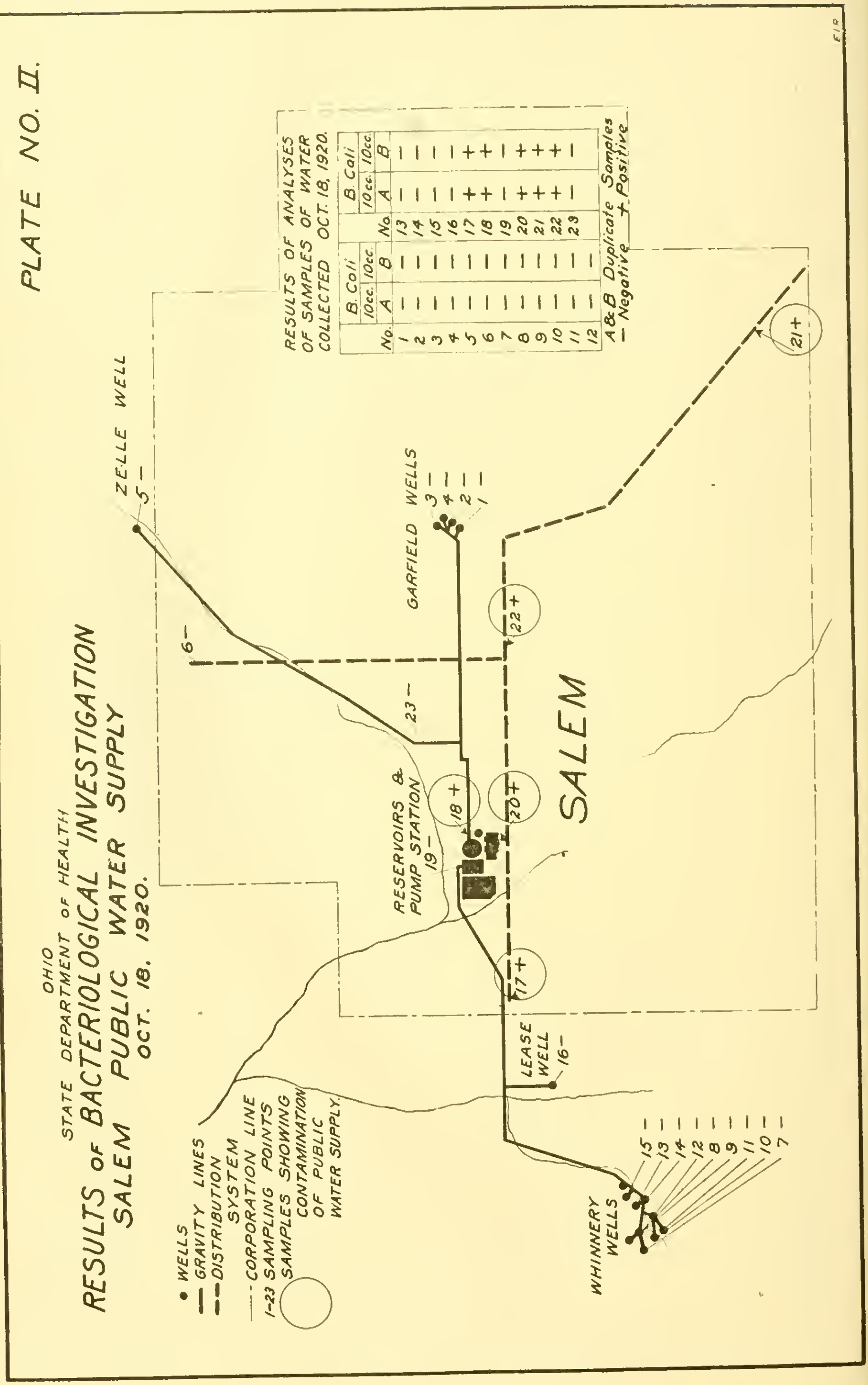


CHART NO. I
OHIO
STATE DEPARTMENT OF HEALTH
CHRONOLOGICAL CHART
OF
TYPHOID FEVER EPIDEMIC
AT
SALEM, OHIO.
RAINFALL IN INCHES.
DATE OF RAIN
INCHES OF RAINFALL
1.0
0.8
0.6
0.4
0.2
0
TYPHOID FEVER CASES.
Chlorination started Oct. 20 1920.
Enteritis prevalent early in Sept. 1920 and continued in varying degrees throut the month
Brooks Sewer plugged Aug. 17, 1920
NUMBER OF CASES.
50
40
30
20
10
0
AUGUST
SEPTEMBER
OCTOBER
1920.
NOVEMBER
DECEMBER
JANUARY
1921
DATE OF TAKING TO BED



No.	B. Coli 10cc. A	B. Coli 10cc. B	No.	B. Coli 10cc. A	B. Coli 10cc. B
1	–	–	13	–	–
2	–	–	14	–	–
3	–	–	15	–	–
4	–	–	16	–	–
5	–	–	17	+	+
6	–	–	18	+	+
7	–	–	19	–	–
8	–	–	20	+	+
9	–	–	21	+	+
10	–	–	22	+	+
11	–	–	23	–	–
12	–	–			

did not affect those persons who had received infection previous to October 20, but it prevented further infection, and subsidence of the epidemic occurred on schedule time. The size of the epidemic was not realized until the early part of November, when reports of cases multiplied, and on November 9, at the request of the city officials, the State Department of Health assumed charge of the local situation and sent representatives to make a thorough investigation and apply necessary remedial measures to prevent the spread of the disease.

Sanitary Investigation.

When the representatives of the State Department of Health undertook the investigation on November 9, practically no accurate information regarding the epidemic was available except the knowledge that the public water supply had been the medium of infection, and that by instituting chlorination on October 20, this cause of the disease had been removed. It became necessary, therefore, to institute a careful inquiry regarding the situation throughout the city, and for this purpose what has been termed a sanitary investigation was made. This comprised a visit to each occupied building within the city and in the built-up district surrounding the city, a total of 2 630 places. Information was obtained regarding cases of illness, and the nature of the same, occurring after September 1; the source of the water supply used prior to illness; the existence of a water-service connection, a private well or other private source of supply, and the existence of a sewer connection, privy or cesspool. In addition, printed notices were left at each place, containing a warning to boil all water used for drinking, and giving instructions regarding disinfection of stools from typhoid fever patients. This sanitary investigation would not have been possible had it not been for the earnest effort of the local War Workers Organization. By the united effort of the members of this organization, the sanitary investigation was practically completed during a period of twenty-four hours, making the information promptly available. The results of this sanitary investigation gave information which was the basis upon which the epidemiological investigation was made and the various remedial measures were applied to check the spread of the disease.

Epidemiological Investigation.

Starting on November 9 and continuing until the epidemic had subsided, a careful and thorough epidemiological investigation was made of each case. The usual information regarding each case was secured, consisting of the date of first symptoms, the date taken to bed, the location of the case, the sex, age and color, and an inquiry to determine the possible exposure factors during the period when the disease was contracted. These factors include the milk supply, the food supply, the water supply, the attendance at public gatherings, and the opportunity for contact infection.

I shall not endeavor to present any details of the results of the epidemiological investigation. All sources of infection were clearly eliminated except the public water supply of the city, which was found to be the common factor. The chronology, distribution, and general character of the epidemic also pointed to the public water supply as the cause. Therefore the evidence established the epidemiological diagnosis "that the contamination of the public water supply was the cause of the epidemic."

Description of Water Supply.

The following description of the public water supply system of Salem applies to the system as it existed prior to the epidemic, and does not include the changes or improvements made subsequently. The Salem Water Company started the development of the present system in 1887, continuing its ownership until 1899, when the Salem Water Works Company succeeded to ownership. In 1909, the system became the property of the city. The water supply is obtained from four general sources, as follows: The Garfield Avenue wells, located immediately northeast of the central portion of the city; the Whinnery wells, located approximately one-half mile west of the city; the Lease well, located approximately one-quarter mile west of the city, and the Zelle well, located immediately north of the city. The water is lifted from the various wells either by air-lift or deep well pumps, and delivered by gravity lines to storage reservoirs located near the main pumping station in the westerly portion of the city, and from these reservoirs the supply is pumped to the distributing system. The general locations are shown by Plate No. II.

The Garfield Avenue wells are very poorly located, being on a tract of land occupied by a high-school building and in a district which is entirely built up with residences, many of which are accompanied by privies and abandoned private wells. There are also sewers and other contaminating influences near the wells. Wells were developed at this site as early as 1882, before the water company assumed control, and these were continued in use until 1898, when additional wells were drilled and the old wells deepened. At this time the water was pumped from the wells directly into the distributing system, but in 1900 air-lift equipment was installed to pump the wells, and a gravity line was constructed extending from the site of the wells to the reservoirs at the main pumping station. The wells have been operated in this manner since 1900. The Garfield Avenue wells are 265 ft. in depth, penetrating 12 ft. of clay, 100 ft. of brown sandstone, 80 ft. of fire-clay or soapstone, and extending the rest of the way through white sandstone. The casings of the wells extend to a depth of about 100 ft., and the water is mainly derived from the white sandstone. The gravity line has a total length of 3 400 ft. and is constructed of 12-in. vitrified, salt-glazed, double-strength sewer pipe in 3-ft. lengths, with deep and wide sockets. Joints were made with cement. The line extends in Green Street and Jennings Avenue, both of which are almost completely built up, and there

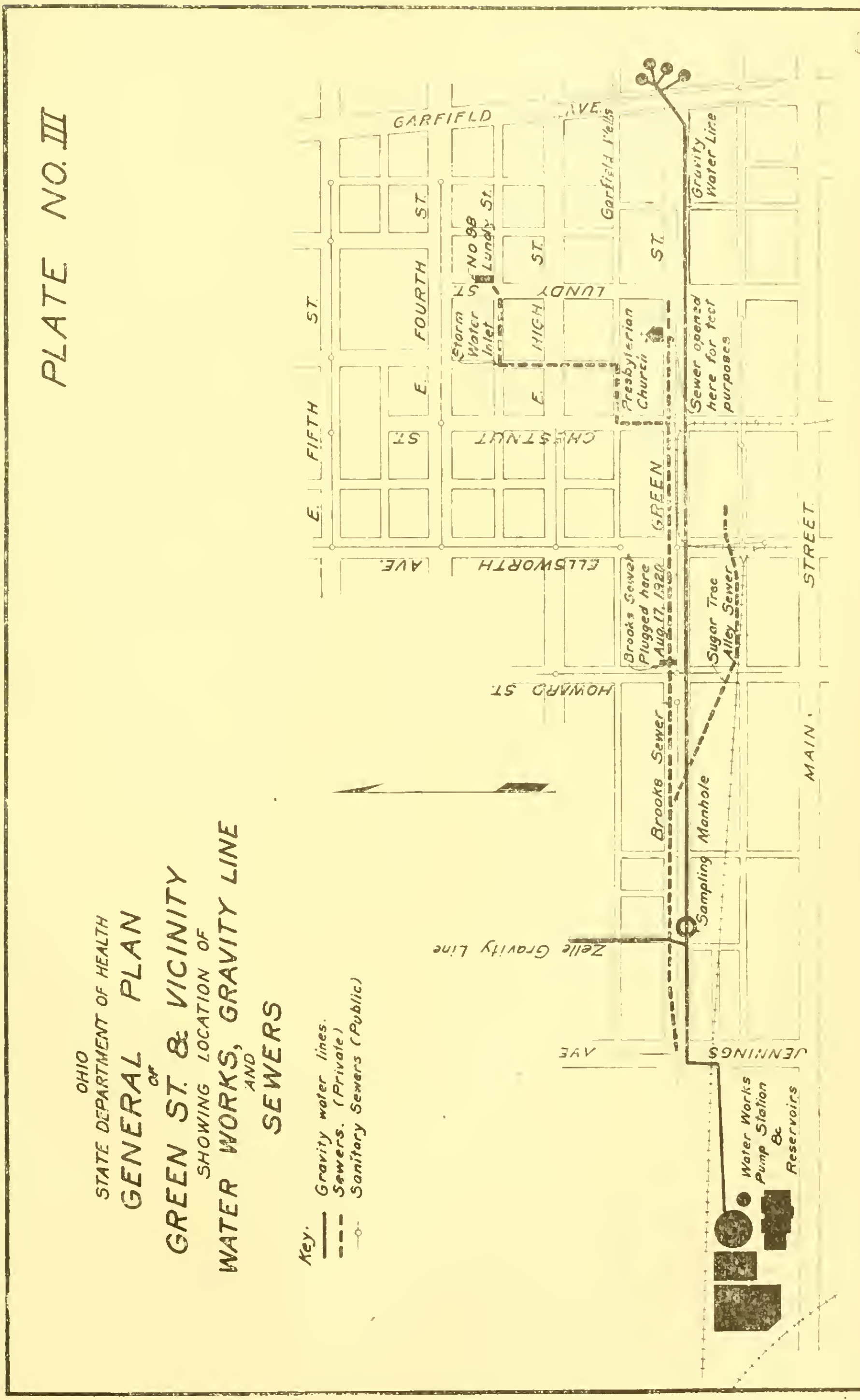


PLATE NO. III
OHIO
STATE DEPARTMENT OF HEALTH
GENERAL PLAN
OF
GREEN ST. & VICINITY
SHOWING LOCATION OF
WATER WORKS, GRAVITY LINE
AND
SEWERS
Key.
Gravity water lines.
Sewers. (Private)
Sanitary Sewers (Public)
GARFIELD AVE.
E. FIFTH ST.
E. FOURTH ST.
E. HIGH ST.
LUNDY ST.
CHESTNUT ST.
ELLSWORTH AVE.
HOWARD ST.
GREEN ST.
MAIN STREET
JENNINGS AVE.
Storm Water Inlet
No. 98 Lundy St.
Garfield Wells
Gravity Water Line
Presbyterian Church
Sewer opened here for test purposes
Brooks Sewer Plugged here Aug. 17, 1920
Sugar Tree Alley Sewer
Brooks Sewer
Sampling Manhole
Zelle Gravity Line
Water Works Pump Station & Reservoirs

are numerous sources of contamination of the shallow ground water along the route of the line. Private and public sanitary sewers parallel and cross the line and are at points at elevations higher than that of the gravity line. The location of the gravity line is shown by Plate No. III. The Garfield well development is unsatisfactory on account of the unfavorable location of the wells themselves, and also on account of the use of a gravity line which subjects the water to dangerous contamination. While these conditions were recognized to be potentially dangerous they had not caused trouble prior to the epidemic. Samples from the wells collected at various times during the past twenty years have given satisfactory results, and this is true also of samples collected from the reservoirs receiving the discharge from the gravity line.

In 1903 it became necessary to increase the water supply, and the Salem Water Works Company started the development of the Whinnery wells at a point about one-half mile west of the city. The original installation comprised six wells, and five additional wells have been installed from time to time since 1903. The site of the wells is satisfactory. The surrounding country is open farm land and there are no nearby sources of contamination. The wells are 180 ft. to 200 ft. in depth, penetrating 85 ft. of clay, 80 ft. of white sandstone, a few feet of limestone and a stratum of black slate. The supply is obtained from the white sandstone formation. Four of the wells are pumped by deep well pumps, and six of them are pumped by air-lift. The water is discharged into a gravity line which extends a distance of some 5 700 ft. in an easterly direction, to the reservoirs at the main pumping station. This gravity line is well constructed of 10-in. cast-iron pipe with leaded joints, and is probably water-tight. The fittings at the tops of the casings of the wells equipped with deep well pumps are apparently tight. Brick cisterns with plank covers are placed around the tops of the wells pumped by air-lift. The covers are not securely fastened and are not tight, and the cisterns in general have been permitted to deteriorate so that the water as discharged from the wells is exposed to possible contamination. This is the only unfavorable sanitary feature of the Whinnery well development. Samples from the Whinnery wells have always shown this supply to be of excellent sanitary quality.

The Lease well, which is located about one-quarter mile west of the city, between the Whinnery wells and the city, was developed in 1914 and is similar to the Whinnery wells. It is pumped by air-lift and is provided with a brick cistern. The same comment made in regard to cisterns at the Whinnery wells applies to this development. Samples from the Lease well have always shown freedom from contamination.

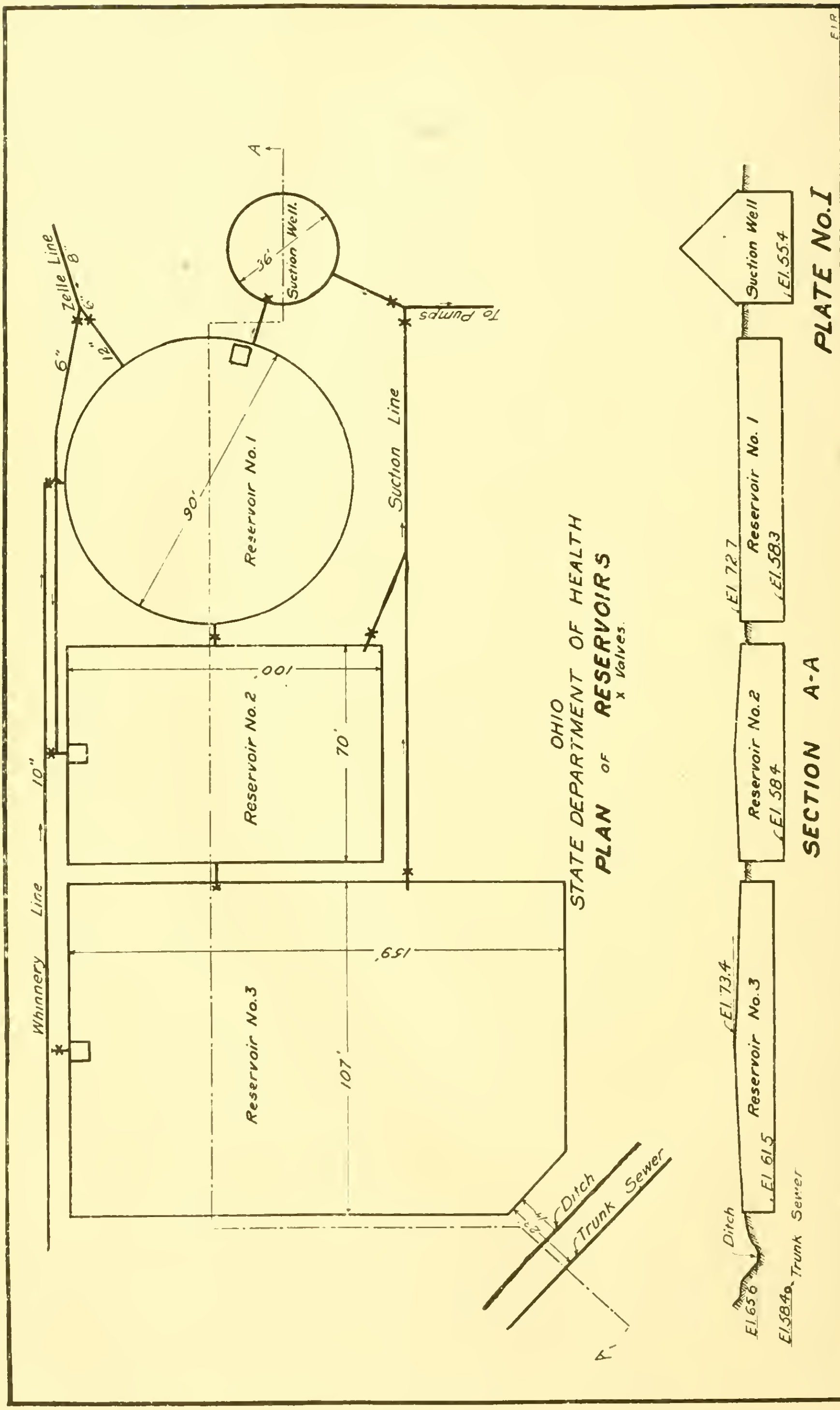
During 1916, the city increased the available water supply by drilling wells on the Zelle Farm, located immediately north of the city. The location of these wells is satisfactory and the city owns a 24-acre farm at this point. Only one well is now in service. This is approximately 180 ft. in depth and penetrates 35 ft. of sand and gravel, 5 ft. of shale, an unknown

thickness of brown sandstone, and an underlying soapstone formation. The well is plugged at a depth of 165 ft. The water is obtained from the brown sandstone formation. The well is pumped by direct suction, the water being discharged into a gravity line constructed of 6-in. cast-iron pipe with leaded joints and extending from the well site in a general southwesterly direction to a connection with the old vitrified pipe gravity line serving the Garfield Avenue wells. From this point the combined flow of the Garfield Avenue wells and the Zelle well is conveyed in the vitrified pipe line to the reservoirs at the pumping station. The tops of the wells at the Zelle Farm are not securely closed to prevent entrance of chance contamination, but otherwise the well development is satisfactory. The gravity line is poorly located, as it extends along the banks of a small stream and is, therefore, subject to washout. Evidence also indicates that the joints of this line were not made properly and that many of them are leaky.

The water from the various sources of water supply delivered through the gravity lines is received in storage reservoirs constructed at various times between 1887 and 1917. These comprise Reservoir No. 1, a circular structure 91 ft. in diameter and 12 ft. in depth, with a stone wall and a concrete bottom and cover; Reservoir No. 2, a rectangular structure 100 ft. by 70 ft. in plan and 14 ft. deep, with concrete floor, walls and cover, and Reservoir No. 3, a rectangular structure 159 ft. by 107 ft. in plan and 10 ft. deep, with concrete floor, walls and cover. In addition, there is a pump well 36 ft. in diameter and 16 ft. deep, with a concrete floor, brick walls, and timber cover from which the pump suction is normally taken. The reservoirs are so connected that water may be discharged into either Reservoir No. 1 or No. 2, and may be drawn to the pumps from the suction well or from Reservoir No. 2 or No. 3. The general arrangement of the reservoirs is shown on Plate No. I.

The condition of the reservoirs and suction well is not satisfactory. The bottoms of all the reservoirs are in a leaky condition and the walls of Reservoirs No. 2 and No. 3 and of the pump well are also leaky. This permits the entrance of shallow ground water into the reservoirs when the water within them is lowered to an elevation below that of the surrounding ground water. This is of particular importance when it is known that the reservoirs are located at about the lowest elevation within the city, to which vicinity practically all of the natural and artificial drainage is directed. The main trunk sanitary sewer of the city passes Reservoir No. 3 at a distance 23 ft. from its west wall.

The water supply is in general use by the citizens of the city, and prior to the epidemic was popularly accepted as a pure supply. It is also made available to the industrial plants of the city which generally maintain private supplies obtained from wells similar to those of the city. Careful investigation revealed existence of a number of cross-connections with the public supply.


OHIO
STATE DEPARTMENT OF HEALTH
PLAN OF RESERVOIRS
x Valves
Reservoir No. 1
Reservoir No. 2
Reservoir No. 3
Suction Well.
Suction Line
To Pumps
Zelle Line
Whinnery Line
Ditch
Trunk Sewer
90'
36'
100'
70'
159'
107'
10"
6"
12"
8"
SECTION A-A
Suction Well
El. 55.4
El. 72.7
El. 58.3
El. 58.4
El. 73.4
El. 61.5
El. 65.6
El. 58.4
PLATE No. I

Summarizing the above description of the water supply system of the city, it will be noted that while the water had for a number of years been considered safe, due to favorable analyses and absence of outbreaks of water-borne disease, there existed at the time of the epidemic a number of defects in the development of the system. For convenience these will be repeated as follows:

1. The location of the Garfield wells is unsafe.
2. The gravity line serving the Garfield Avenue wells is of unsafe construction, probably not water-tight, and as it passes through the built-up portion of the city the water supply is thus rendered subject to contamination.
3. The tops of the various wells are not securely closed.
4. The iron pipe gravity line serving the Zelle well is poorly located and has poorly leaded joints.
5. The reservoirs have leaky walls and bottoms, subjecting the water supply to danger of contamination by shallow ground water.
6. Connections to the water-works mains exist, whereby private water supplies may reach the distributing system.
7. While not directly connected with the sanitary safety of the water supply, mention must be made of the inadequacy of the supply, which has caused several severe shortages during recent years.

Manner in Which the Water Supply became Contaminated.

Recognizing the various defects of the water-works system, it became necessary to determine beyond reasonable doubt the manner in which the public water supply became contaminated and thus caused the epidemic of typhoid fever. The investigations and studies of this matter required much time and painstaking care, and obviously consideration of each defect was demanded. The first investigation, made October 18 and 19, including bacteriological examination of samples, indicated that the contamination was reaching the water supply through the vitrified pipe gravity line serving the Garfield Avenue wells, and these results warranted the presumption that this was the cause of the epidemic. Plate No. II shows these results. Accordingly, in addition to chlorinating the water supply, beginning October 20, the use of this gravity line for the Garfield Avenue wells was terminated October 27, as soon as pumping equipment could be installed and the water delivered directly into the distributing system. It was necessary to continue the use of the power portion of the vitrified pipe gravity line for conveying the water from the Zelle well until December 3, when a new cast-iron line was completed. A careful consideration of the various defects of the water-works system finally eliminated all possible causes of contamination except the vitrified pipe gravity line. Taking up each of the defects, it may be advantageous to indicate how they were eliminated.

The possibility of deliberate or accidental contamination of the water supply through the tops of the well casings cannot be eliminated definitely, but this does not appear as a probability, particularly in view of the fact

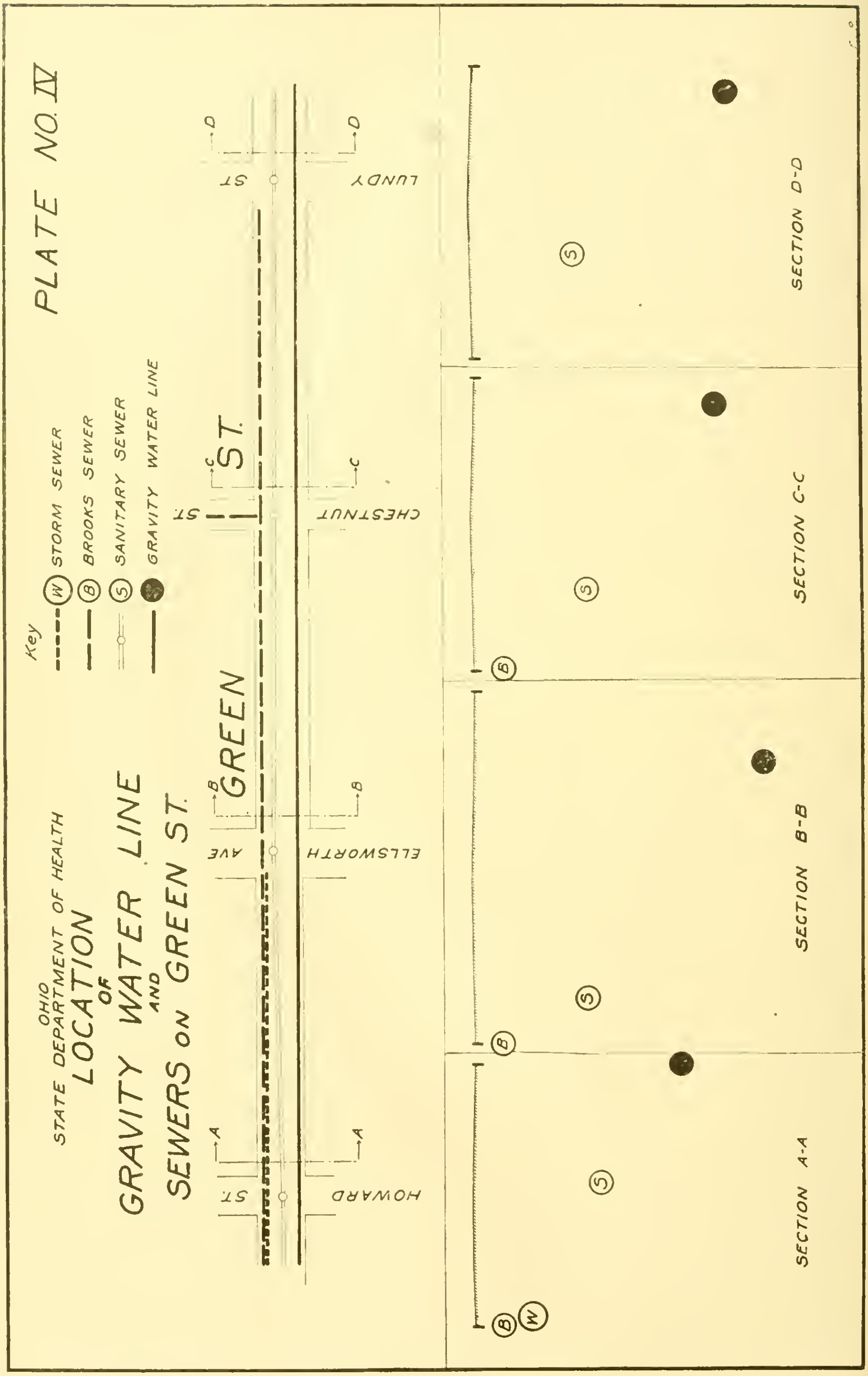


PLATE NO. IV
OHIO
STATE DEPARTMENT OF HEALTH
LOCATION
OF
GRAVITY WATER LINE
AND
SEWERS ON GREEN ST.
Key
W STORM SEWER
B BROOKS SEWER
S SANITARY SEWER
GRAVITY WATER LINE
GREEN ST.
HOWARD ST
ELLSWORTH AVE
CHESTNUT ST
LUNDY ST
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D

that the history of the epidemic indicates that the water supply was infected on more than one occasion during the time the outbreak was developing.

Direct contamination of the Garfield Avenue wells probably did not occur, as samples collected from them for a long period of years prior to the epidemic and during the period of investigation after the epidemic started did not show contamination.

The cast-iron pipe gravity line serving the Zelle well under certain circumstances might have admitted contamination through a leaky joint, but this possibility is removed by the evidence that the line was under internal pressure continuously from the spring of 1920 until October, 1920, at points where it would be possible for contamination to reach the line. Furthermore, analyses of samples from this line failed to show contamination.

The cross-connections on the distributing system, permitting discharge of water from private industrial water supplies, are not held accountable, due to the fact that these supplies are generally of the same character as the deep well supplies of the city, and, furthermore, the distribution of cases throughout the city would not correspond with contamination in this manner.

In spite of the unsatisfactory construction of the reservoirs and pump well at the main pumping station, a careful investigation produced evidence showing that these structures were not responsible for the typhoid fever outbreak. Evidence was obtained showing that at no time during the summer of 1920 did the level of water in the reservoirs fall below that of the shallow ground water surrounding them. A test was conducted to determine whether it would be possible for sewage to pass from the main sanitary trunk sewer of the city to Reservoir No. 3. This was done by plugging the sewer so as to place it under a head of 6 ft., adding at the same time to the sewage a considerable quantity of uranine, which is a very intense green dye. Previously, Reservoir No. 3 had been completely emptied, and it was noted shallow ground water seepage entered through the walls and bottom. This condition was permitted to continue for slightly more than one hour, and samples of the seepage reaching the reservoir were regularly collected, but failed to show evidence of the uranine color.

The study of the vitrified pipe gravity line serving the Garfield Avenue wells gave conclusive results that the water supply was contaminated by leakage of sewage into this line. This line extends in Green Street and is paralleled by a sanitary sewer, a storm sewer and two private sewers. One of these private sewers, known as the Brooks sewer, was installed a number of years ago for private use, but was later connected to the sanitary sewer system of the city and was continued in use as a combined sewer. Not only did it receive sewage from a number of residences and a church, but it also received the surface run-off from a built-up area of several acres, this reaching the sewer through a catch basin near its upper end. The Brooks sewer was constructed with open joints, and the pipe was without bell ends.

It, therefore, must have been leaky. A storm sewer paralleling it had discharged sewage for several years, and a nuisance had been created at the outlet. This sewage was probably reaching the storm sewer by seepage from the Brooks sewer. An effort was made by the employees of the city to correct these conditions, but it was impossible to discover what dwellings were connected to the Brooks sewer. Therefore, on August 17, 1920, a plug was inserted in the Brooks sewer, at Howard and Green streets, by employees of the city, with the thought in mind that sewage would back up in this sewer and flood cellars of dwellings connected to it, thus bringing about complaints which would expose the existence of connections to the sewer. However, no complaints arose, and apparently the sewage continued to leave the Brooks sewer through the open joints without backing up sufficiently to flood cellars. With these conditions existing, heavy rainfall occurred during the last four days of August, 1920. This was followed by an outbreak of enteritis. Other heavy rains occurred September 9, September 27, September 30, and October 1, and apparently were the forerunners of the typhoid fever epidemic.

While all of the evidence strongly pointed to soundness of the belief that the Brooks sewer and the gravity line were the causes of the epidemic, it appeared necessary to prove the possibility of passage of sewage from the Brooks sewer to the gravity line. In an effort to do this, a sampling manhole was placed on the gravity line near its lower end, where the seepage leaving it could be observed, sampled and measured. It was soon found that the seepage was contaminated ground water, and that the rate of flow was influenced by rainfall. A concentrated salt solution was introduced into the Brooks sewer above the plug, and at the same time the Brooks sewer was filled with water from a fire hose to imitate surcharging such as would be caused by rainfall. Careful examination of samples from the gravity line showed an appreciable increase in the chlorine content, 30 parts per million being present before the test and 46 parts per million after the salt was applied. This was not considered to be sufficiently conclusive, and further tests were made using uranine. This was applied at the storm-water inlet to the Brooks sewer, at the same time filling the sewer with water from a fire hose. Within two hours after this dye was applied at the storm-water inlet, a definitely noticeable green discoloration appeared in the seepage from the gravity line at the sampling manhole. Allowing for the time for flow in the Brooks sewer and in the gravity line between the storm-water inlet and the sampling manhole, the time for transfer from the Brooks sewer to the gravity line could not have exceeded thirty minutes. These investigations established conclusive evidence that the typhoid epidemic at Salem was caused by the passage of sewage from the Brooks sewer to the gravity line. Important confirming evidence is furnished by the fact that about October 1 there was a case of typhoid fever in a dwelling connected to the Brooks sewer, the stools from which were flushed directly into this sewer.

Measures Taken to Control the Epidemic.

The placing in operation on October 20 of a disinfection plant to treat the public water supply of the city at the main pumping station effectually checked the epidemic. This was the most important step taken to prevent the continued spread of the disease. Added safety was secured by abandoning the use of the vitrified pipe gravity line for delivery of water from the Garfield Avenue wells on October 27, and by the reconstruction of the lower end of this line, using cast-iron pipe which was placed in service for the delivery of water from the Zelle well on December 3. An added measure of safety was provided by placing in operation on December 11 a liquid chlorine machine to treat the water pumped from the Garfield Avenue wells into the mains. Daily analyses of the water as delivered to the consumers indicated that after the disinfection of the supply was started the water was safe for drinking purposes at all times.

Owing to the intensity of the epidemic, however, and particularly recognizing the results of the sanitary investigation, it was deemed advisable to place in effect other measures to prevent the spread of typhoid fever. The sanitary investigation revealed the existence of some 276 private dug wells, 127 private drilled wells, and many cisterns throughout the city. The majority of these wells and cisterns were old and unused prior to the epidemic, but owing to the suspicion which was aroused regarding the public water supply the people generally turned to private sources of drinking-water supply. Accordingly, it was felt that some definite measures should be taken to protect the inhabitants of the city from disease which might arise from the use of such private supplies, as such supplies were in constant danger of contamination by the discharges of typhoid fever patients. Public warnings were given against the use of dug wells and springs, and, in addition, 100 dug wells and 37 cisterns were disinfected by applying to each one pound of hypochlorite of lime. This effectually prevented the use of such wells.

The sanitary investigation revealed the existence of 441 privies, the most of which were of improper construction. As it was thought that many of these had been used by persons suffering from typhoid fever infection it was deemed advisable to attempt disinfection of these privies. Accordingly, each privy vault in the city was treated with approximately five pounds of hypochlorite of lime.

Particular emphasis was placed upon the disinfection of stools from typhoid fever patients, and to facilitate this a supply of hypochlorite of lime in 1-lb. tins was secured by the city and distributed without cost to families in which cases of typhoid fever existed.

It was not known what effect the sewage from the city might have upon the population downstream from Salem, and it was deemed justifiable to attempt disinfection of the sewage at the sewage treatment plant. For this purpose, a dry feed chlorine gas machine was installed to treat the

settled sewage. The amount of chlorine applied was approximately five parts per million, which was the maximum capacity of the machine. No bacterial results are available to show the efficiency of this treatment. On the Ohio River below the mouth of Little Beaver River are several communities in Ohio and West Virginia obtaining their public water supplies from the stream. Each of these communities was notified of the existence of the typhoid fever epidemic in order that they might take precautions in the treatment of their water supplies.

Pasteurization of the entire milk supply of the city was effected. Fortunately, a large milk depot had been established at Salem and was equipped with efficient pasteurizing machines, making possible the treatment of the entire milk supply of the city. Regulations were also enforced prohibiting the leaving of milk containers at premises where typhoid fever existed, and prohibiting delivery of containers to purchasers at groceries and other places selling milk. These measures continued in effect until the epidemic had subsided.

Prevention of the spread of the disease through contact is attributable to the efficient public health and private duty nursing service which was provided. Over 300 nurses responded to the general call for help, and as a result every patient in the city received daily nursing attention. Too much credit cannot be given to the nursing service for the prevention of the spread of the disease through contact and for the low mortality rate.

Inoculation was generally taken advantage of by the people. It is estimated that at least 4 000 persons were inoculated. These included all of the food handlers of the city.

Unusual medical service attended the treatment of this epidemic. The seventeen local physicians were assisted by three volunteer physicians from neighboring cities and six consultants. Dr. Henry A. Christian of Boston, Mass., did most to accomplish the proper treatment of the cases, to which must be attributed in a large measure the low mortality rate. Hospital facilities included five hospitals, four of which were improvised. The total capacity, 180 beds, was taxed during the peak of the epidemic.

Recommendations Made to Prevent a Recurrence of the Epidemic.

The outstanding recommendations made by the State Department of Health to the city officials to prevent possibility of a recurrence of the typhoid fever epidemic relate to improvement of the public water-supply system. The following were the principal items of advice regarding the water supply:

1. To continue chlorination of the water supply until improvements in the system could be made which would insure a safe water supply at all times.

2. To provide extensive improvements of the water-supply system to insure an adequate water supply of good quality, and pending the completion of such improvements to take the following steps:

3. To abandon permanently the Garfield Avenue wells, requiring increase of the other sources of water supply.

4. To abandon permanently the vitrified pipe gravity line. This has been done.

5. To repair the cast-iron pipe gravity line serving the Zelle well field.

6. To protect all wells from contamination by securely closing the tops of casings.

7. To abandon or make water-tight the storage reservoirs at the main pumping station.

8. To require abandonment of unsafe private wells.

The foregoing recommendations have not been fully carried out to date, but the city has learned its lesson and is taking steps to follow these recommendations fully.

In addition, recommendations were made to the city that legislation be passed providing for the proper control of the use of the sewers of the city in order to secure the use of the same in accordance with the purposes for which they were designed. Progress has been made looking toward the carrying out of these recommendations.

In order to provide proper control of the milk supply, sanitary inspection of dairies by the city was recommended and continued pasteurization of the milk supply to the city until the epidemic had entirely subsided.

Lessons Learned from the Epidemic.

While the epidemic involved a great loss in life, money, and efficiency, it produced facts the recognition of which will prevent the occurrence of other epidemics of similar cause. The outstanding fact is the necessity of proper construction and maintenance of public water-supply systems. No city can afford to overlook this fact. All features of construction and maintenance of the water-supply system must be of highest standard to insure continuous safety. Another lesson learned is the necessity of analysis of the public water supply at regular intervals, regardless of its reputed quality. Had these lessons been learned and followed at Salem prior to the epidemic, it is safe to say that the epidemic never would have occurred.

As a result of the Salem experience, the General Assembly of Ohio in 1921 passed a law intended to provide better control of public water supplies in Ohio. This law contains the following principal features:

1. It gives the State Department of Health general supervisory control of all public water supplies.

2. It requires the municipality or owner of the system to have analyses made regularly.

3. It prohibits dangerous emergency supplies and cross-connections between public and private water-supply systems.
4. It empowers the State Department of Health to require changes and improvements in public water-supply systems to insure safety.

It is believed that the proper enforcement of this law will accomplish much in the prevention of water-borne typhoid fever in Ohio.

Discussion.

Mr. J. W. Ledoux.* There is one feature which seems to be very impressive, and that consists in laying a low-pressure water-supply pipe parallel to and close by a sewer which may be acting at a higher head. Even if this water pipe had been of cast iron and laid in the best manner possible, joint and other leaks are liable to subsequently exist, and with a terra-cotta pipe leakage was sure to exist, because there is not one man in a hundred who can be depended on to lay a terra-cotta pipe water-tight. In case of leakage, the sewage was sure to get into the pipe. The remedy would be either to design the system so that the water pipe would be under higher pressure than in the sewer or else to change the location entirely. The serious feature seems, to me, should have been anticipated in the beginning.

Mr. Knowles. There is no doubt it could have been, and I agree with you that it should have been anticipated. It is undoubtedly true that typhoid fever usually comes from things which could have been prevented. This was a tile pipe line which had open joints, and the sewer had open joints. Of course the thing could have been prevented by having tight lines or a pump with greater pressure so that the water would have gone out. Analysis would have told them there was danger, and they ought to have had continued analyses all the time. They trusted to the fact that the supply had had a good reputation for years.

Mr. Frederic I. Winslow† (*by letter*). The paper of Mr. W. H. Dittoe, read by Mr. Morris Knowles at Bridgeport, is one of remarkable interest. It seems very much like the system in vogue in the old days in New England homesteads, where the privy and the well were placed side by side for general convenience. It is also not wholly unlike the case in England many years ago, where hop-pickers, brought down to the fields from London to gather the crop, camped on the soil, which happened to be marked by many crevices. The campers used the ground freely, with the result that the discharges found their way into a neighboring water supply and an epidemic of typhoid was the result. In the Salem case there appears to have been either culpable negligence or gross ignorance in the

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† Consulting Engineer, Framingham, Mass.

laying of the sewer and water pipes, when they must have been known to have been in close proximity; aside from the policy of collecting water for drinking purposes from a district where sewers existed in plenty. Incidentally, this case emphasizes the necessity and difficulty of maintaining a water supply without contamination, and a case came in the writer's experience some years ago where a mild epidemic of typhoid attacked various sections of a town deriving its water supply from driven wells. The cause of the outbreak was never definitely ascertained; but a few years after the epidemic the writer found a connection into the fire piping of a large factory from a foul stream, and it transpired that a fire had occurred in this place at about the time of the epidemic, making it at least extremely probable that the connection was the cause of the trouble. It seems impossible that no one in the town of some intelligence knew of this possible danger and through lack of courage or energy did not like to make it known.

SOME OBSERVATIONS CONCERNING WATER-SUPPLY MAINS.

BY J. W. LEDOUX.*

The selection of the size and character of pipe or conduit is an important duty of the designer of a water-works system.

When there are required sizes 24 in. and upwards and pressures over 50 lb. per square inch, where strict economy and satisfactory results are essential, a consideration of the various types of pipe obtainable is advisable.

Some conservative designers would decide the matter offhand in favor of ordinary cast-iron pipe, which they estimate to be so far superior to all other types in all practical essentials as to leave no room for argument.

In a large part of the United States, especially in the districts yielding limestone or hard waters, where the soil conditions are favorable, this position could not be seriously criticized, because the initial leakage should be immaterial, the cost of maintenance nominal, the lasting quality indefinite, and cast-iron pipe can be obtained readily in the competitive market throughout the East and Middle West.

For the soft waters of New England and other states, the mountain regions and the colored waters of the Atlantic Coast, cast-iron pipe is under a disadvantage, and supply mains will lose a large portion of their carrying capacity within a very few years. Instances of small sizes losing 60 per cent. and large sizes 30 per cent. of their original capacity within twenty years are common. It is true the pipe can be cleaned and the original discharging capacity restored, but the effects of such cleaning seldom last long, so that in a short time, sometimes within a year after cleaning, the results are as bad as before, so to maintain the flow the cleaning has to be repeated frequently.

Where the pipe has been designed with a large over-capacity, little trouble is noticeable to the water-works owners, who seldom investigate until they are in trouble, when an additional main is installed, which might have been postponed indefinitely if the pipe had retained its original capacity

It is remarkable what a large reduction in discharge capacity tubercles will cause without materially reducing the internal volume of the pipe. In one case a 4-in. cast-iron pipe was tested in service and found to have a coefficient of 26 per cent. A typical section was taken out and its volume determined by filling with water. The tubercles, which were soft, were then cleaned out and the pipe again filled with water; when it was found

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the tubercles had occupied only $3\frac{1}{2}$ per cent. of the internal volume, and yet their roughness had the effect of reducing the pipe's discharge capacity by 74 per cent. which was later proved by cleaning a thousand feet of the pipe, when the coefficient was restored to 100 per cent.

While there are other objections to cast-iron pipe, such as liability to electrolysis, inability to resist the corrosive effects of acid soil found in the coal mining regions and in cinder banks along the railways, these are insignificant when compared with the reduction in carrying capacity.

If a 16-in. pipe is good for 3 000 000 gal. per day, and its capacity is reduced by 20 per cent. and water is worth 5 cents per 1 000 gal., there is a theoretical loss of $30 per day, or over $10 000 per year.

While water-works engineers have for many years recognized this vital defect of cast-iron pipe, the knowledge is now becoming so widespread that many minds are casting about for a substitute that will retain its carrying capacity; and it is to be hoped that in the near future a material will be found that will combine all the virtues of cast iron, but will not rust or tuberculate. In fact, it has been alleged that such an iron or metal alloy can now be produced at commercially permissible prices.

It is sometimes held that success can be attained by a suitable coating or paint, but these have all been tried without permanent success. Copper, tin, lead or zinc lining offers better possibilities of success, but they are expensive. Cement lining is undoubtedly a certain protection, but it is expensive and has to be applied of such thickness as to materially reduce the discharging capacity. There is also an apparent difficulty due to the inability to make the inner lining continuous; but it is believed that material corrosion or tuberculation of the iron will not take place in the dead spaces separating the ends of the cement lining.

Cement lining has its best application in connection with wrought-iron or steel pipe, as has been proved by over thirty years' experience on a scale large enough to be conclusive. The only difficulties were with the joints, the tapping, and the competition with cast-iron pipe. But this kind of pipe became discredited, due to certain pipe contractors who tried to reduce the cost by cheap workmanship and the use of lean mortar.

For low head and large sizes, reinforced concrete is practical and successful, particularly since good and economical expansion joints have been designed. For high heads, it will in all probability be necessary to use a thin sheet-steel tube within the reinforced concrete.

Some firms are now ready to furnish, install, and guarantee this class of pipe for mostly any conditions and pressure. It has the great advantage that it can be fabricated complete in large quantities at or near the site of the installation, which is impracticable with any form of metal pipe.

Wood pipe has for many years been exploited and used as a substitute for cast-iron pipe. Where the material, design, and construction have been good and the conditions suitable, these pipe installations have been satisfactory for pressures below 150 lb. per square inch.

However, many mistakes have been made, — sometimes through undue zeal to secure a contract, but generally due to ignorance and lack of skill, which seem to be a frequent accompaniment of this line of activity.

There are two distinct types of wood-stave pipe, — the factory-made and the continuous. The former also varies in form of joint and in steel reinforcement; the commercial type being machine spirally banded with mortise and tenon joints. Another type is a machine spirally wire wound, and still another form, where the steel reinforcement consists of independent rods and malleable cast-iron lugs. The wood staves vary from $1\frac{1}{2}$ to 3 in. thick, $1\frac{7}{8}$ in. being the most common thickness.

With the continuous wood-stave pipe the staves are usually of less thickness, but independent rods and lugs are universally used. In any case the use of a soft wood is imperative, and preferably a wood containing no knots or other imperfections. Clear white pine, Norway pine, redwood and fir are the woods that should always be used, but occasionally some unscrupulous contractor tries scrub, or sap pine, with eventually bad results.

In a continuous wood-stave pipe, the staves of the proper quality and shape, the metal strips, and the independent rods and lugs are sent from the factory to the ground and there put together by men experienced and skillful in this line of construction. The iron hoops are properly spaced for the pressure, and are screwed together and made tight on the pipe by screwing up by hand operation. The material coming on the ground in that form readily lends itself to thorough inspection, and in this respect the pipe has the advantage over the factory-made pipe, which is all fabricated complete, except the end joints, but in the continuous pipe the tension on the rods depends on the uniform skill of the workmen. Undoubtedly some of the rods must be tighter than others, and the water pressure being uniform will subject these tight ones to the greatest pressure.

The safety of the pipe, therefore, under these conditions is undoubtedly due to the fact that the wood will accommodate itself by abrasion so that each rod will take its portion of the stress. If it were not for this effect the continuous wood-stave pipe would not be so reliable as the factory-made pipe, where the bands are wound on the pipe by machinery under uniform tension. The factory-made pipe has an additional advantage that the iron bands are readily protected by dipping and revolving the surface of the pipe in a hot asphaltic material, and afterwards rolling in sawdust. This forms an excellent protection, which cannot be done satisfactorily after the pipe is put in the trench. Another advantage of the flat bands is that they do not indent the pipe as do round rods.

But even if the pipe be first class in every respect, unfavorable conditions of installation and operation will soon cause trouble and undeservedly injure its reputation.

Where the soil is dry and porous and the pipe not continually subjected to a fairly strong pressure, the wood will not last many years, and

where a wood pipe is used as a pumping main and subjected to high pressure for a part of the time and to very low pressure for long periods, there is sure to be trouble due to leakage of the joints and the staves. There are some soils of a silty nature in which wood and iron will last indefinitely, even if the pipe is not subjected to material pressures. The ideal condition for a wood-pipe conduit is where the entire pipe is always subjected to fairly constant pressure. Such a condition is obtained by pumping to an elevated reservoir kept constantly supplied with water, and, when the pump stops, the pipe is under the pressure of the reservoir. If the friction when pumping is such that the pressure at the pumping station is, say, 75 lb. per square inch, and when the pumps stop, only 30 lb. per square inch, the conditions can be considered good. In a gravity main, if the pressures at the inlet and outlet ends are always not less than 20 lb., and not greater than 150 lb., the conditions may be considered good, provided the pipe is not operated under a low pressure for a long period and later under a much higher pressure.

As an example of very bad practice, a 24-in. wood pipe was laid along a salt marsh for many miles from the pumping station to a standpipe; the pumps usually worked from eight to fifteen hours per day. The pipe was not entirely submerged in the soil, and the tides covered and uncovered the pipe every day. Soon a considerable amount of leakage resulted, to avoid which the owners of the water works installed at the standpipe a check valve, which closed as soon as the pumps stopped. This allowed the pipes to become practically empty and accumulate air. Naturally, conditions rapidly became worse, so that in a few years the pipe was in bad condition and discredited. For a condition like that it would have been much better to have laid the pipe exposed on supports above the action of the tides, and accessible for inspection and repairs; then it should have been subjected always to the pressure of the standpipe even when the pumps were stopped, and no check valve should have been installed.

Another case consisted of a 24-in. wood pipe ten miles long. This was machine spirally banded, and the joints were mortise and tenon. The wood was of Norway pine, 2 in. thick. The pumps worked at about two and a half million gallons per day, which subjected the pipe to a pressure at the pumping station of 18 lb. per square inch. The outlet was in the bottom of a reservoir about 6 ft. deep, and when the pumps were stopped, the pipe was subjected to 12 lb. per square inch hydrostatic pressure. The country was very flat; there were no elevations more than 28 ft. above tide. The pipe was laid with an average cover of about $2\frac{1}{2}$ ft., and crossed under the deep ditches of the various farms, these ditches being from 1 000 to 3 000 ft. apart and some 3 to 6 ft. deep. The result was that the line consisted of a series of summits and depressions at the ditches. While there was a large amount of leakage at first, this gradually took up, so that after a year the total leakage was not more than 50 000 gal. per day. After five years of operation under these conditions it was decided to pump at the rate of 8 000 000 gals. per day through the line, which would cause a pressure at

the pumping station of about 60 lb., but the iron banding was originally good for 80-lb. pressure, so there was no difficulty on this score.

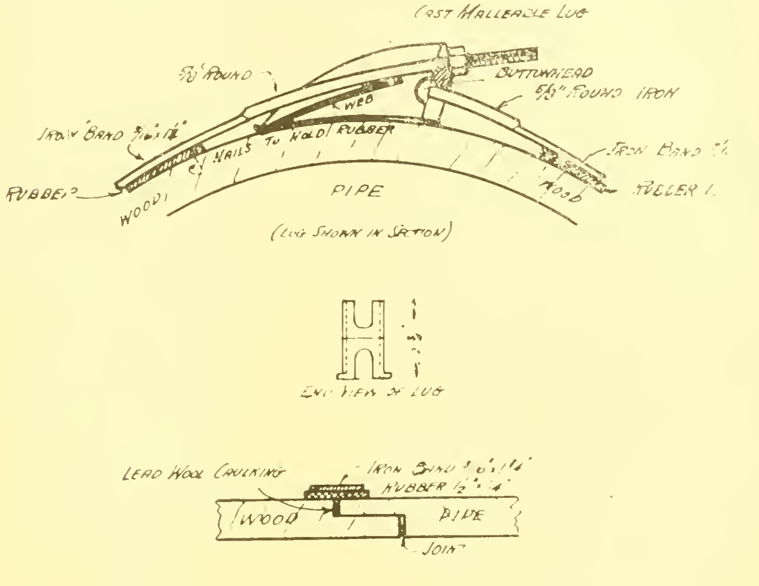
Duplicate electrical pumps were installed, and when the first was ready to operate, water was pumped through the line at the rate of about 5 000 000 gal. per day; pumping pressure 30 lb. per square inch. The leakage was inordinately high. In order to locate this leakage, line valves were successively shut and pumping was continued with a by-pass to the suction well, open sufficiently so as not to cause a pumping pressure of more than 30 lb. It was found in the first 11 000 ft. under this pressure there was a leakage of 4 600 000 gal. per twenty-four hours, or nearly the full capacity of the pump; and that a slight reduction in pressure reduced the leakage materially. An examination of the line showed that this leakage took place in nearly every joint and along the stave joints for the first five miles, the amount increasing near the pumps.

After many days' tests and examinations, it was decided to repair the joints of the first two miles, and band the first mile with independent $\frac{5}{8}$-in. round rods and double lugs, spacing the rods $4\frac{1}{2}$ in. apart.

After this work was done, a test of the first section was made, subjecting the pipe to about 65 lb. pressure, and the leakage was reduced from 700 000 gal. under 21 lb. pressure to 100 000 gal. per twenty-four hours under 65 lb. pressure.

Before a satisfactory repair joint was designed, many experiments were made. The first, designed by the manufacturers of the wood pipe, consisted of a steel band clamp, 4 in. wide, about $\frac{1}{4}$ in. thick, spaced around the joint and clamped at the top by means of a bolt, using tarred jute between the clamp and the pipe. These were only temporarily successful, and, besides, very costly. The next plan was as follows: 6-in. steel bands placed over the joint, leaving $\frac{1}{2}$ in. space, were made in two sections and bolted together, and, the joint having been calked previously with lead wool or jute, the space was then filled with leadite. This also did not prove successful, because the leadite soon deterioated the material, particularly the bolts, so that within a week or more they broke under pressure. Pure cement was then used, which proved successful and permanent, but the cost was high on account of the large bell holes that were required to make a good job at the bottom of the pipe; and the trench was wet, which increased the difficulty. Finally a joint was devised which proved practical, economical, and successful. The joint was scraped off all around the pipe, and at the top for a length of 12 in. it was calked with lead wool. A strip of rubber 75 in. long, $1\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. thick was stretched around the pipe and centered directly over the joint and tacked on the pipe at each end, leaving a space between the ends of about 6 in. Upon this was placed a wrought-iron hoop $\frac{3}{16}$ in. thick, $1\frac{1}{4}$ in. wide, and made taut by a bolt and lug. There were two ways of making the band. One was to forge one end into a $\frac{5}{8}$-in. round for a space of 4 in., leaving a button head on the end; the other end was forged into a $\frac{5}{8}$-in. round for 7 inches and a $\frac{5}{8}$-in. standard thread cut

for the distance. A single standard malleable iron lug was used, as shown in this sketch. The other method of making the bands proved the most practicable. A $\frac{5}{8}$-in. round rod was flattened out to the required thickness and width by means of a steam hammer, leaving the ends the required shape. It was found best to bend the rods to circular form at the place of fabrication. These rods could readily be put in place by average men after two or three days' practice. The work was done without interrupting the service of the pipe line, but before back-filling the trench a valve was



SKETCH SHOWING METHOD OF BANDING
24" WOOD PIPE JOINT

closed and the pressure brought up to the maximum, and any joint that leaked was tightened at the lug and the bands hammered on the sides where necessary.

An attempt was made to substitute for the rubber band $\frac{1}{16}$-in. sheet lead, which was far less costly; but this was not nearly as satisfactory on account of its lack of flexibility, so that it was very difficult to stop the leaks, especially where the surface of the pipe had any irregularities. Besides, many years' previous experience under like conditions had proved that the rubber effected permanent repair.

After the first mile was made tight by banding the entire pipe and renewing each joint, it was found that stave leaks could be stopped by driving hardwood wedges between the iron bands and the staves at the horizontal center of the pipe, so it was not necessary to put independent rods and lugs on more than about 8 000 ft. of pipe, and it is quite likely that if the

subsequent conditions were known in the beginning, even the first mile would not have had to be treated in this manner.

After the repairs were made in what was considered a sufficiently satisfactory manner a test was made of the entire 40 000 ft. of pipe pumping through the line at the contract rate, equivalent to over 8 000 000 gal. per twenty-four hours. The leakage was found to be about 200 000 gal. per twenty-four hours, which was determined by making a Pitot tube measurement at both ends of the line, while the pumping continued at the same rate. The Pitot tube was checked by means of a Venturi type of meter at the pump end, and the discharge at the upper end was checked also by means of a rectangular weir, but the close measurement of leakage was determined in the following manner. While the pumping was going on at the contract rate, pressures were taken every mile and recorded. Then at the pumping plant a 2-in. by-pass with a 2-in. Empire meter was laid around a main valve. The line was then divided arbitrarily into six sections, the division points being the existing gate valves. The sixth valve, or farthest from the pump, was closed and the pump was kept working at the regular rate, discharging sufficient water into the suction well through the by-pass until the pressure at the pumping station equaled that which was previously found on the sixth section, and the discharge through the Empire meter recorded.

Then the fifth valve was closed and the same pressure maintained on the line. The Empire meter reading was then recorded, and the difference between these two gave the leakage on the sixth section. The by-pass was then closed sufficiently to subject the line to the pressure corresponding to that previously found on the fifth section, and the meter reading recorded.

The fourth valve was then closed and the remaining part of the line subjected to the pressure previously found for the fifth section, and the meter reading again recorded. The difference between these last readings represented the leakage on the fifth section.

In this way the entire line was tested, and the sum of the separate leakages represented the total leakage on the line under normal conditions.

At the pumping station the maximum pressure when pumping through the entire line was about 58 lb. per square inch, and the pressure at the far end for the test was not more than 13 lb., so under these conditions the Empire meter did not have to discharge at any time at a higher rate than 70 gal. per minute

There was one very important feature, without which it would probably have been impossible to have repaired this line at all, and that consisted of the use of white-pine sawdust, which was applied in the following manner: A connection was made with the suction of the pump and the bottom of an open barrel, which was kept full of water by a spigot at the top. Sawdust was stirred into this barrel, and the valve to the suction opened a sufficient amount so as to apply about 100 lb. of sawdust an hour. The pump was run at full rate, and a calculation was made to determine when the sawdust would reach a certain line valve. This was then shut by pre-arrangement

and the by-pass opened back to the suction, so that the pressure on that portion of the line would be no greater than it would be under regular operation. The sawdust would then stop the leaks, and discharge through the line was determined by the station meter. In this way the entire line was treated, and the leakage immediately reduced by at least 50 per cent., and the effect was permanent, not so much due to the sawdust as to the following condition:

This pipe had been subjected to only 18-lb. pressure for the first four years, and the earth fill over the top of the pipe had exerted sufficient pressure to gradually flatten the pipe, so that by test it was found that the horizontal internal diameter was $25\frac{1}{2}$ in. and the vertical diameter $22\frac{1}{4}$ in. A similar condition prevailed practically through the length of pipe. When the high pressure was put on, the pipe assumed a circular form, which could be seen by a crack along the surface of the ground over the pipe. Naturally this resulted in the leakage at the horizontal diameter of the pipe, and at the joints. After operating the pipe a considerable time under the higher pressure, a large amount of the leakage took up naturally, and it is quite probable that if this principle had been recognized in the beginning a great deal of the repairs could have been avoided by simply using sawdust at once and then maintaining the pumpage at the maximum for several weeks. Without the sawdust the high pressure could never have been secured, as the amount of leakage was so great as to cause trouble to the land all along the right of way. It is probable, however, that a considerable amount of the joint work could not have been avoided in any case. This experience proves how important it is to maintain a wooden pipe line at nearly the maximum pressure to which it is to be subjected, because wood being an organic substance will gradually accommodate its shape to the forces acting upon it.

An interesting feature in connection with this concerns the coefficient of discharge. Before the repairs were made, the coefficient was 95 in Chezy's formula, and afterwards 111. That is about the difference that would be caused due to the change in the hydraulic mean radius, resulting from a round pipe and one flattened as indicated.

Many exploiters of concrete, wood and even steel pipe try to create the impression that the coefficient of discharge is superior to that of cast iron, but it is believed for a given shape the coefficient of discharge depends on the degree of roughness and not on the character of material of the interior surface.

Discussion.

Mr. Ledoux. I should like to ask if there are any members here who know of any distribution systems that have been laid of wooden pipe, and whether they have been satisfactory for any length of time.

Mr. Allen Hazen.* I remember the water supply of Du Bois, Pa., laid in that way, that had the curious effect of reducing the sulphates. There was some mine water in it, and as the water ran from the pipes the hydrogen sulphide in it was very disagreeable.

Mr. Burt B. Hodgman.† I have had some experience with wood pipe and also with cleaning pipes. Mr. Ledoux has said that certain pipes deteriorate after cleaning in one year. That is quite true. But we do not believe that to be so as a general rule, any more than you should discard cast-iron pipe because it breaks, or steel pipe because it pits. But there are places where cleaning is stood off for ten or fifteen years.

In regard to wood pipe, I had considerable experience in Spokane, Wash., where I tested out with a pitometer something like 30 miles of distribution pipe from 4 in. to 8 in. in diameter. It was not satisfactory under those conditions because of the great changes in pressure, varying from 18 lb. during the high irrigation hours to 90 lb. under normal conditions. Leaks developed almost everywhere, and a little too fast to stop.

Mr. Arthur W. Dudley.‡ Wood pipe is in use at Antrim, Troy, Campton, Freedom, Pembroke, Penacook, Hudson, and Bristol, N. H. The pipe at Antrim and at Penacook are the oldest installations, having been in service twenty-five and twenty-four years, respectively, and have given perfect satisfaction; that at Penacook is now incorporated with the Concord, N. H., water system. The Campton pipe was laid under the direction of the writer in 1908, and that at Freedom in 1912; the maximum pressure at the former is 104, and at the latter 120 lb. Both are in perfectly satisfactory condition, and have never developed leaks or other trouble since their installation. Pembroke and Troy were constructed in 1914, under my supervision. At both of these places the supply lines are wooden pipes, and the distribution systems cast-iron pipes, with the exception that the line on Pembroke Street, some $4\frac{1}{2}$ miles in length, is wood pipe. The supply line, from Lake Pleasant in Deerfield, N. H., to Suncook village, in the town of Pembroke, slightly over 14 miles, is laid with 16-in., 14-in., and 12-in. wood-stave pipe. About $3\frac{1}{2}$ miles of the lower end of this 12-in. pipe, before entering Suncook village, is under a head of from 286 to 312 ft. This pipe was laid with the greatest care by a representative of the pipe factory under the close supervision of the writer, and has never yet shown the least indication of leakage or any other trouble. At Troy, N. H., they have $2\frac{1}{2}$ miles of 12-in. supply pipe. Here we had a rather singular experience. My inspector reported several leaks, and asked me to advise

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‡ Civil and Hydraulic Engineer, Manchester, N. H. (*by letter*).

him what to do; I could not go there at the time, and when I went, several days afterwards, we were utterly unable to find them, and they have never since been discovered. They were undoubtedly over dry joints that soon swelled up and have since remained tight.

At Hudson and Bristol they have supply lines, laid under the supervision of a Nashua engineer, that, as far as I know, are satisfactory. There are also extensions at Lisbon, N. H., and at Northumberland, N. H., where short lines of wood pipe have been installed. The only failure that I have any knowledge of was at Peterborough, N. H., where 600 ft. put in last winter, by a careless and inexperienced party, without any supervision, had to be relaid. This pipe was dropped in any which way, the joints not more than half driven, and big stones thrown into the trench on to the pipe; and as it was under a pressure of 126 lb. it was a foregone failure.

Mr. Hazen. There is a physical limit to the pressure which can be carried in wood pipe. I will tell you my personal basis for that. Some years ago we were designing some pipe where there were a good many trolley tracks, and we wanted to put in some insulation joints. They were in fashion then. We thought that wood pipe was the easiest way to get a good insulation, and these were made of as good design and of as good material as we could find; but when we came to the test they could not be made tight. We had rather high pressures, running up to 150 lb. We could not get hoops that would hold that pressure without crushing the wood fiber. The leakage was not very great, but the pipes could never be made tight.

I was telling that to a manufacturer of wood pipe in his factory, one day. We were using miles of such pipe during the war. And he said, " Oh, we can band pipe to stand a pressure " — I have forgotten what he said, — 200 lb., we will say. I told him my experience. He said, " Let me show you." They had a testing machine, and a piece of pipe built for high pressure, and put it in. The pressure was put on. " See, it doesn't leak," he said. It was just a matter of definition. The pipe was sweating all over, but there were no jets of water from it. How much it would leak in a mile I do not know. But the manufacturer of that pipe said, " It is tight; you can see it stands; it does not leak."

Mr. J. W. Diven.* The last piece of wood pipe put in in Elmira, was put in in 1875. That pipe was banded, and it did stand a pressure of 110 lb. It was a force main from the pump to the reservoir. The pressure at the pump end was 110 lb. The pipe was tarred and rolled in sawdust and tar, and rolled in sawdust again to protect the bands. There was no appearance of sweating on the outside of that pipe at 110 lb. pressure. But that was a bored pipe, and the shell was 4 in. thick.

Mr. Ledoux. In 1908 we laid 7 000 ft. of wood pipe on the Monongahela Division of the Pennsylvania Railroad. This was part of the large system of the railroad supply comprising some 600 miles of pipe from 12 to

* Secretary, American Water Works Association.

36 in. in diameter. For this particular section wood pipe was selected on account of the necessity of laying it in a cinder fill. The makers of the wood pipe assured me that they had a coating which was absolutely proof against corrosion due to the acid of cinder banks, and I took a chance. The working pressure was specified to be 150 lb. per square inch, and that is the pressure that was actually on the line. When the pipe was first laid there was very much leakage, which continued about two weeks and then gradually decreased until it practically disappeared. The leakage was measured by means of a small meter on a by-pass around a valve at the inlet connection of the cast-iron pipe. This pipe continued to give good satisfaction for nearly two years, after which it began to give serious trouble. It was found that the iron bands had been so eaten through by the acid in the cinders that it was decided to replace the entire line. If the soil had been neutral I have no doubt the pipe would have continued to give good results.

I do not believe there is any coating made that will withstand those conditions, and I am sure that cast iron would not have stood for more than two or three months, an opinion which was confirmed by other similar experience, so that we found it necessary under conditions of that kind to encase the cast-iron pipe in concrete.

This 7 000 ft. of wood pipe, however, was replaced by cement-lined pipe manufactured by the American Pipe and Construction Company of Philadelphia, and in answer to a recent inquiry I learn that there has been no trouble with the pipe since it was laid. Unfortunately, the above company stopped making that kind of pipe.

Mr. W. C. Hawley.* Since such a large amount of sectional wooden pipe was used by the Government during the war, I am wondering if some water-works men who were in the service can give us an idea of the leakage to be expected from this class of pipe.

I had an experience some years ago which did not convince me that the manufacturers had very much confidence in it. I designed a 12-in. cast-iron pipe line as a supply line from a reservoir, and the manufacturer went to my client and wanted to sell him the sectional wooden pipe at quite a saving in cost. The price was a very important thing to that company; but, on the other hand, leakage was even more important, because the amount of water which could be collected from that source was limited and every gallon was needed. The matter was referred to me, and I finally made a proposition to the manufacturer that if he would give a guaranty that his pipe line would, for a period of five years, be as tight as we would expect a cast-iron line to be, we would put it in. Of course when we began to talk he was perfectly confident that the pipe line would not leak and willing to "guarantee" it, but when it came to putting a bond back of that guaranty he would not do it.

I put a short piece of pipe, a 12-in. section, in a force main, some years ago, to increase resistance to the flow of electricity and thereby to prevent

* Chief Engineer, Pennsylvania Water Works Co.

damage from electrolysis. The pipe was put into a trench which was in the rock, and the bands or wire on that wooden pipe lasted not over three or four years.

Mr. Diven. Steel or iron?

Mr. Hawley. I do not know. We replaced it, and the new pipe has been in service now some twelve to fourteen years, and we have had no further trouble with it.

As to the maximum pressure on a continuous wooden-stave pipe, my recollection is that 90 to 100 lb. is considered the limiting economical pressure, for above that the amount of steel required in the bands becomes equal to the amount of steel in a sheet-steel pipe, and there is no economy.

Mr. Diven. I think about 1860 the white pine, of which the wood pipe was made, sold for about $87. The same wood to-day is worth something like $400, and hard to find at that.

Mr. Frederic I. Winslow* (*by letter*). The experience of the city of Boston in the use of a 30-in. cement-lined wrought-iron pipe laid by the city of Charlestown in 1870, before its annexation to Boston, shows that a large pipe of this material has a life of at least fifty years, if — emphasis on this *if* — it is undisturbed, and is laid in solid ground. The only trouble comes when it is necessary to make connections with it, to insert a gate; or when it has been mistaken by an over-enthusiastic laborer for a sewer.

On the other hand, all of the smaller sizes of cement-lined pipe similarly made have long since been relegated to the scrap-heap, as the iron skin corroded. A suggestion originally made by the late Freeman C. Coffin, I believe, contains a valuable contribution to this subject, namely, the use of a cast-iron pipe lined with cement. This has never been carried into effect, so far as I am aware.

It would be very difficult, I fancy, to induce New England water-works men to introduce wooden pipes to carry heavy pressures, or even as low as Mr. Ledoux states they are safe at; although at many of the war plants wooden pipe was used for sewer work.

If the remarks regarding the short life of a cleaned pipe are true, it would necessitate the organization of a pipe-cleaning department in larger cities.

Mr. J. J. Wilson. The author points out that, for water-works pipes 24 in. in diameter or larger, a consideration of various materials is advisable. Among such materials, lap-welded steel pipe, which has been used for water mains for the last thirty years, and which has lately become available in much larger sizes, merits consideration. Steel pipe has gained much ground the last few years because of evident advantages, among which are its general reliability and economy. The reliability of steel pipe has been proven through thirty or more years of service, during which time remarkably few failures have been recorded. This reliability under severe conditions is due to the strength of steel and its ability to withstand strains

* Consulting Engineer, Framingham, Mass.

without breaking. An instance of this nature occurred during the summer of 1921, when during a severe flood at Colorado Springs, Colo., washouts occurred which left a line of steel pipe suspended for a span of 150 ft., without interruption to service. The Baltimore high-pressure fire system, of steel pipe, has been installed for ten years without a serious leak or break. Many other instances could be cited. The economy of steel pipe lies in the fact that it is relatively cheap in first cost and to install, considering the service it gives. Many instances are on record of installations lasting for periods of twenty-five to thirty years without serious corrosion troubles. A 24-in. diameter disk, cut from a 48-in. steel main in Pittsburgh, after twenty-five years showed no measurable corrosion. Some failures of early installations of steel pipe may be attributed to a lack of knowledge of proper methods of protection against corrosion. Steel-pipe coatings have now been developed to such an extent that corrosion of the interior is in most cases negligible, with the result that the carrying capacity of steel pipe is not lessened with age to nearly the same extent as cast iron. Outside corrosion can be effectively prevented by proper coating to withstand conditions. In most pipe lines, soil conditions vary at different places in the line, corrosive influences at some places being more severe than at others. Extra protection should be provided for the more dangerous places, and with the present knowledge of causes of corrosion and means of prevention, such protection as will best meet conditions can be readily applied.

Perhaps the best proof of the service of steel pipe lies in the fact that almost all cities that have once used steel for their large mains, use the same material for extensions. The city of Rochester, which has been cited as having experienced considerable corrosion in the first steel conduit installed there, decided in favor of steel for its third conduit on the basis of general reliability and ultimate economy.

Recently a large plant has been installed by the National Tube Company, for manufacture of hammer-welded steel pipe from 24 in. to 96 in. diameter, in lengths up to 40 ft. Lap-welded pipe was previously made by the old process in sizes from 2 in. to 30 in. diameter.

THE DISAPPEARANCE OF THE COATING FROM CAST-IRON PIPE WHILE STORED IN THE YARD.

BY SAMUEL E. KILLAM.*

[*Read September 14, 1921.*]

Coating for cast-iron pipe to be used as a water supply is a subject about which much has been written during the last century. Many experiments have been made, all in the hope of finding a coating for the pipes which would give a perfect protection against the formation of tubercles after the mains had been put into service. The results of these experiments with coating have been almost negative, and the delivery capacity of the mains after they have been put in service gradually decreases until we find after fifteen to twenty years the delivery has been reduced 25 per cent.

On the Metropolitan Works of greater Boston it is necessary to maintain storage yards for large amounts of pipes and special castings for use on emergency repairs, as part of the system was acquired from the city of Boston and the remainder was laid under specifications adopted by the Metropolitan Water Works and the New England Water Works Association. Similar conditions exist on all extensive works.

During the twenty-five years in which the pipe has been received from the foundries there has been very little change in specifications as to the requirements of the coating on pipes cast.

The requirements for coating under present specifications are as follows:

"Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle, nor with any tendency to scale off.

"Each casting shall be heated to a temperature of 300° F. immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the bath. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

"The varnish shall be heated to a temperature of 300° F. (or less, if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

"Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be re-coated shall first be thoroughly scraped and cleaned."

* Superintendent, Distribution Section Water Division, Metropolitan District Commission, Boston.

There is in storage, in the Metropolitan yards, pipes and special castings valued in stock at about $70 000. Many of these castings have been stored for about twenty-five years. A considerable number of these still have only the original coating, although places have been touched up with a brush where the coating was injured in transit or in handling in the yards.

Good coatings on pipes in storage will remain smooth and tough, softening from the heat during the summer months, and show no tendency to crack or scale off in cold weather.

In recent years the coating has been affected by the atmospheric conditions in from five to ten years after the pipes are received from the foundry. The pipes are stored in the yards on skids, but the coating on the interior surfaces is in many cases as much affected as the exterior surfaces.

It is impossible to protect in open storage the coating on special castings such as caps, plugs, etc., as the moisture collects in the depressions and within a few months the coating will entirely disappear.

On many pipes received from the foundries the coating will begin to disintegrate in rings 4 to 6 in. wide about $2\frac{1}{2}$ ft. from the bell and spigot. This rusting and disintegrating of the coating is believed to be caused by the fact that the pipes are rolled on skids at the foundry before the coating has had sufficient time to harden.

During the war some pipes were received at the yards from the foundries, which had been passed by inspectors, where the coating had entirely disappeared on an area of several square feet, sometimes on the inside and sometimes on the outside surfaces. The coating had vanished in transit, leaving the pipes uncoated and rusty. The inspector and foundry officials were unable to explain why the coating had disappeared. A complaint was forwarded to the foundry and the coating on the remaining shipments of pipe was satisfactory.

In 1866 engineers of the French navy made many experiments with pipe coating. At last they perfected a coating nearly like our coal-tar product of many years ago. A pipe was coated and submerged in salt water for one year, and at the end of that time it was found that the coating was in good condition, but, as far as the writer has been able to learn, nothing further ever resulted from these experiments. Compare this test, if you will, with that actual test of the coatings on the cargo of pipe bound for New Bedford some years ago, when the barge sank off shore and in about two weeks the coating which remained was so poor that it was necessary to clean and cold-dip all of the pipe before they could be salvaged.

Coal tar of to-day is very different from the coal tar of seventy-five years ago and the products from various gas works differ widely as to ingredients. It has been said that during the latter part of the war any black semi-fluid that came from the gas works passed as coal tar.

Dr. Smith's process, of which you all have heard, calls for dipping cold pipe in hot tar for half an hour, or until the pipe gets thoroughly warm.

Can you imagine our foundries of to-day, with their enormous output, allowing each pipe to remain in the coating for this length of time?

A foundry owner recently said to the writer that the makers of cast-iron pipe were perfectly willing to give the consumers what they wanted if the consumers were willing to pay the price.

The writer believes very strongly that as engineers and water-works men we should be in a position to specify what materials are required and the method to be followed in coating pipes and special castings.

Do we know what we want? If not, are we willing to pay the price to find out what combination of materials makes the most durable coating and are we willing to pay the additional cost for that coating?

Discussion.

Mr. Allen Hazen.* The Spring Valley Water Company of San Francisco has met a similar condition by establishing and operating a dipping tank in its yard. In this tank all old pipe, and all defective pipe, and new castings made locally, and, in short, any pipe there is any reason to question, is re-dipped immediately before it is laid. It is not a very expensive matter for the company to keep up this tank and operate it occasionally and it is a satisfactory means of overcoming that difficulty, and tends to maintain the high standard of the company's work.

I want to add also that I think the time is coming, or perhaps has come, when better specifications for coating cast-iron pipe ought to be adopted. In riveted pipe made of steel and wrought iron much better coatings have been used. They cost more money, but are worth it. I am inclined to think that as good coating as is actually put on steel pipe would pay dividends on cast-iron pipe.

Mr. J. M. Diven.† Did they heat the pipe before dipping it, in San Francisco?

Mr. Hazen. Yes; I won't say the same as at the foundry, but it is heated a great deal.

Mr. Franf A. Barbour.‡ Of course this question of coating is a very live issue with your Committee on Standard Specifications for Cast-Iron Pipe. We had a meeting this morning, and voted, among other things, to send a communication to the manufacturers, asking them to state whether they would be willing to coöperate with us in the development of a better coating. That involves experimental work and a considerable expense, and it is necessary for us to know how far the manufacturers will go. There is no doubt that a great many of the manufacturers at the present time are experimenting with different pipe coatings, and that they fully realize that the present coating is not satisfactory.

* Consulting Engineer, New York, N. Y.

† Secretary, American Water Works Association

‡ Consulting Engineer, Boston, Mass.

At the meeting of the American Water Works Association I had something to say for the committee of that association, and one or two men representing towns came to me and said that they believed their water boards would be glad to contribute something towards the development of a better coating. Whether that would be practicable, or whether this Association, or any other association, should accept money in that way for such an investigation, I do not know; but there are certainly a great many men who feel that it is one of the big issues.

Mr. Diven. There is no good reason why the Association should not accept, or even ask for, contributions for such a purpose, as with the very small dues it could not be expected to do research work. The result of such work would be of great benefit to many water works, and if attempted by them individually would certainly cost each many times the small contribution needed from each to create a fund to permit the association to do the work thoroughly.

The process of gas making has been radically changed, and it seems probable that the production of gas tar has also changed or possibly been greatly reduced by the change from coal gas to so-called water gas.

The speaker has never noticed that the coating of valves deteriorated more than that on pipes, though it is his understanding that they are not dipped, but painted with some cold preparation or composition, as the heating of a finished valve to the required degree for dipping would be apt to warp it.

Mr. Killam spoke of the inventories of pipe and specials on hand, and the charge for them when used. Were these made on the cost price or the replacement price?

Mr. Killam. Original cost; what we call the " stock value." Every pipe that comes in the yard is listed, the original cost, including cost of transportation and handling. This stock value is entered on cards, and when the pipe or special is delivered to the works it is charged off to that piece of work.

Mr. William R. Conard.* Mr. Hazen spoke of the Spring Valley Water Company having facilities for re-coating their pipe. The city of Springfield also has facilities for doing that work in their pipe yard. They have installed a coating tank and an oven for heating the pipe and for heating the coating. Some years ago, when they were able to make a purchase of a quantity of pipe at a nominal figure, on which the coating was in rather a poor condition, they bought the pipe with the understanding that they would re-coat it at their own expense. That was one of the objects of making the purchase, which was at a low figure.

Speaking of the cargo of New Bedford pipe which deteriorated so rapidly, the cost of the re-coating was at the expense of the insurance company. The type of coating which was used was, as Mr. Killam said, a cold dip, or paint. It was a structural steel paint which was purchased, and

* Inspection Engineer, Burlington, N. J.

which at the time was rather costly, although the insurance company, in order to make an adjustment, and have the cargo accepted, was very glad to furnish the materials. That pipe was re-coated by building a wooden tank and filling it with the cold dip, and simply lowering the pipe in and coating the same as though they had been previously heated. There were no facilities at that time to heat the pipe, and because of the character of the coating which was put on it was not necessary to re-heat it. Some two or three years after that pipe had been re-coated I looked at some of it in the storage yard at New Bedford, and the coating had, as we term it, weathered very well, — it was still in good condition.

Practically all gate valves are painted cold, the material being applied with a brush. The interior of the body and the bonnet, after the machine work is done on them, are painted inside, then the valves are assembled, tested, and afterwards the exterior and the inside are painted for the second time.

Most of the valve manufacturers use what is termed an " asphaltum " paint.

Mr. Killam. I haven't any doubt but Mr. Conard can tell us if the material for pipe coating that is used at the foundries is purchased from gas works.

Mr. Conard. Nowadays the coal tar is controlled practically by one concern, — the Barrett Manufacturing Company. Practically all the coal tar used by the pipe foundries is purchased from the Barrett Manufacturing Company. Even after the gas company gets through with it, I understand the Barrett Manufacturing Company tries to get some by-products out of it.

Mr. Hazen. I have been recently assured by a competent representative of the Barrett Company that they could still sell tar of the old-fashioned quality. I think it is possible to get this tar of the same chemical analysis; but chemical analyses may not tell the whole story, and I do not feel sure that there may not be differences with analyses that seem to be the same. The methods of chemical analyses of coal tar were developed by Dr. Dudley, of the Pennsylvania Railroad. Dr. Dudley gave this matter a great deal of attention and determined the kind of coal tar which gave the best results as a protective material in railroad work.

Mr. Conard. I am very glad to hear Mr. Hazen say something about there having been at some time a thorough analysis of coal tar. I have tried time and time again to get hold of some such information. I don't know whether that information might be available or not for the consideration of the Pipe Specifications Committee — I think they would be very glad to have it if it could be made available. They should also find out whether the various components were ever determined, and what their effect might be on iron.

Mr. Barbour. I might say that the tentative specification which has been used by the committee for some four or five years contains a specification for coal tar which was largely based, I think, on what Mr.

Hazen used on the Springfield line, and I think that specification is probably based on what he refers to as Dr. Dudley's work.

Mr. Hazen. That is correct.

Mr. Barbour. So that it is already in our tentative specification. If we could get that, I think we could get real tar.

Mr. Hazen. I knew Dr. Dudley very well. He was one of the ablest scientific thinkers of the country. I do not know whether he ever published anything about his coal-tar work, but at the time of the Springfield work I asked Dr. Dudley, as my personal friend, to give me the benefit of his experience in writing the specifications; and the specifications thus drawn have been used, with some slight modifications, ever since.

Mr. Diven. Does any one know whether in the manufacture of water gas, which is coming to be very general, any gas tar is produced?

Mr. Hazen. I think that is an entirely different kind of tar. It is some time since I have been through a water-gas plant. I think that they do produce tar, but that the tar is of a different quality, and probably not suitable for coating.

WATER-WORKS ACCOUNTING.

[*September 15, 1921.*]

(Discussion and Adoption of Committee Report presented at 1920 Convention; published in the JOURNAL for March, 1921.)

PRESIDENT SHERMAN. The subject scheduled for this evening is that of water-works accounting, which was reported upon to this Association at its convention last year. The report, as your program advises you, was published in our last March issue of the JOURNAL. It was received at the Holyoke Convention and laid on the table pending its publication, as it was obviously a type of report which it was impossible to discuss without seeing the detailed forms recommended by it. No discussion was possible at that time. It is now in print, and it has been in the hands of the members for several months.

The report is now before you for consideration.

MR. SAMUEL H. MACKENZIE.* As one member of the Accounting Committee, I regret very much that Mr. Hathaway, who was on that committee and who, perhaps, is the best-qualified member to discuss it, is unable to be present to-night; nevertheless, as we have had ample time to consider the matter, it seems wise to bring it before the meeting for discussion; and in order that definite action may be taken I will offer the following resolution:

Whereas, at the present time in this country all privately owned and operated public water works are universally classed and recognized as public utilities, and as such are amenable to uniform accounting and other operating requirements prescribed by the public utility commissions of the several states; and

Whereas, municipally owned and operated public water works are likewise recognized and classed by the best and most competent authorities as public utilities (by some governmental authorities called "public service enterprises") instead of political subdivisions of municipal government; and in a growing number of states such municipally owned water utilities are also amenable to similar uniform accounting requirements as are the privately owned water utilities; and

Whereas, it is an undisputed fact that, in order that the operation of the municipally owned water utilities may compare favorably with the operation of the privately owned water utilities, the former will need to

*Engineer for Water Department, Southington, Conn.

adopt more of the efficient and businesslike practices of the latter, — one of which is the general use of a uniform accounting classification (such as is prescribed by the state public utility commissions), — so that proper and informing comparisons of results may be easily made between such water utilities; and

Whereas, a special committee of the New England Water Works Association has made an exhaustive study and report upon the present need of uniform accounting for municipal water works, and has recently submitted in outline a simple but comprehensive accounting classification in accordance with the latest essential requirements as prescribed by the best and generally accepted authorities:

Now, therefore, be it resolved, by the members of the New England Water Works Association, in annual convention assembled at Bridgeport, Conn., September 15, 1921, — recognizing and appreciating the facts set forth in the foregoing preamble, and desiring to further strengthen the Association in its enviable position as a leader of practical progress in water-works operation, — that this Association hereby adopts, as a standard, the Classification of Uniform Accounting for Municipal Water Works as submitted September 9, 1920, by its special committee and published in the Association JOURNAL for March, 1921; and earnestly recommends its use by any and all of its members to such extent and as soon as they may find it convenient and practicable to do so.

In presenting this resolution, I do it in conjunction and with the sanction of Mr. Hathaway, and it is done in order that this matter may be brought before you for discussion. If there is anything in the suggested form that does not meet with your approval, or could be improved upon, the committee hopes that you will make the fact known.

The classification as submitted to-day is in the hands of the Connecticut Public Utility Commission, and a conference is to be held in regard to it. But, as has been stated by our President, we think that we could bring it before the state authorities with more authority if it were adopted by the New England Water Works Association.

Accounting may be one of the disagreeable sides of the water-works business. It has to have a financial end, and if the plants or water works do not have a correct and proper system of accounting they cannot be run as they should. It is absolutely necessary, if the lines of defense which have been mapped out for us are to be carried out, that we should prepare for them; and if the plants are not run on a businesslike basis those lines of defense cannot be carried out. There is no commodity which is as necessary and important to the welfare of the human race as water, and it is our business to supply as good water as it is possible for us to secure. But that cannot be done without funds. Rates should be adjusted so as to furnish ample funds for the necessary requirements, and sufficient income collected year by year so that unnecessarily high rates will not have to be adopted

when the time comes to make extensive changes or renewals in our plants. As the population about our water supplies increase, many of us will have to adopt some of the lines of defense mentioned here to-day, and there is no better way to prepare for that time than by establishing a proper reserve for depreciation and charging adequate rates to care for the same and other necessary improvements.

President Sherman. The resolution submitted on behalf of the committee which prepared this report is before you for consideration. Is the motion for its adoption seconded? — (The motion is seconded.) It is moved and seconded that the resolution as presented be adopted. I might say, in continuance of what Mr. MacKenzie said in regard to the Connecticut Utilities Commission, that it is my understanding that the Massachusetts Public Utilities Commission is preparing a standard form of accounting for water companies, which is to be promulgated probably within the next two or three months, and I think that a form officially approved by this Association would doubtless receive careful consideration by the Utilities Commission in drafting their standard form. I have had personal occasion to give considerable study to the standard forms of accounting prescribed by the Maine Utilities Commission, and they agree very closely with the schedule as here laid out; in fact, the principles are identical. The only differences would be in names of accounts, and of course would be of no particular moment. Is there any discussion of the form of the report, or on the adoption of the resolution?

Mr. Bertram Brewer.* If anyone attempts to compile financial statistics about various water works, especially municipal works, from the annual reports, one is appalled by the lack of accurate information about the most essential facts, to say nothing of those covered by this comprehensive form; and while I believe in church spires and other things of that nature, it would be a pity to have the ideal so high as to discourage the local superintendent or accountant from inaugurating very much needed reforms which are really of a very simple nature. Probably it will not.

For instance, there is already the standard form of financial statistics of the Association which I believe the President has had some experience in trying to have adopted by the various water-works departments, and we all know with what success. If that simple form of financial statistics had been prepared and printed from year to year by all the water-works departments of Massachusetts it would be a simple matter now, for instance, to find out what each community has paid year after year for maintenance or for construction expense, and what the gross revenue amounted to,— things which every practical water-works man wants to know and every taxpayer ought to know. It is impossible to do this, with any degree of accuracy, in far too many cases to-day. My query is as to whether this new form will help the situation. Perhaps it will. I should like some light on it. I can see how you can pick these and many more facts from the vari-

*Assistant Engineer, Massachusetts State Department Public Health.

ous items in the schedule proposed, but if you cannot secure adoption of the simpler form already recommended, how can the adoption of an elaborate one be secured? It seems a pity that something more cannot be done to secure more uniform municipal accounting and a clear, balanced statement each year of the income and outgo, and perhaps I can emphasize this need by asking these questions.

If the President will pardon me for doing so, I should like to call attention to a balanced financial statement which is made annually by the Belmont Water Works. I have in my hand a copy of the last annual report, and I can say that it is a pleasure to get the reports of the Belmont Water Works. Any one can tell at a glance, from the annual financial statement, how much it is costing Belmont to supply water to its inhabitants and whether it is a paying or a losing business. Furthermore, the Belmont statement furnishes an admirable opportunity to compare this works with others.

Perhaps I am altogether wrong in thinking for a moment that adoption of this standard form is not going to help along the happy day when the townspeople who own the water works can tell just what are the results of their business venture in the procuring and distribution of this essential commodity.

PRESIDENT SHERMAN. I can say that from my point of view the adoption of this would help along just what Mr. Brewer is anxious to get. These forms recommended by our committee have to do with purely financial accounting; the book-keeping end, as you might call it, as distinguished from the superintendence or the operating end. It is impossible for the superintendent or the operator of the work to divide up his operating expenses or to find out how much per foot it costs him to lay pipe of a certain size until the book-keeper has put down the expenses and put them in the proper accounts. The main object of these forms is to get accounts which will lend themselves to subdivision into the several classes desired.

My own feeling in regard to this report is that it has been very carefully thought out by men who, it seems to me, are the very best water-works accountants we have among our members, and that we are probably in a position to make the best progress by adopting their recommendations. It is offered by the committee as the best thing they can present, and we hope the members of the Association will use it, but it leaves us perfectly free to amend it whenever it seems desirable to do so; for instance, if the utility commissions should make rulings which were at variance with recommendations here to such an extent as to require a change in the forms, it might be desirable, and in any such case our committee probably would come back and recommend that our forms be modified to correspond.

MR. BREWER. That is just the information that I really wanted on the matter. Then, as I understand it, in most of the cities and towns, as things are organized, this sort of form would be taken care of by the auditor.

President Sherman. Precisely.

Mr. Brewer. It is a form for him more than it is for the practical operator?

President Sherman. Oh, yes, the book-keeper or the auditor, or the town treasurer, or whoever it is that does the accounting work.

Mr. Brewer. It would not discourage the operator from getting out the very best he could in a simple manner along the lines that I have indicated?

President Sherman. It is my belief that he would get the figures he wanted from the auditor, and with more satisfaction. Of course, as far as prescribing this thing is concerned, in most of our states at the present time it relates only to private companies. The Utility Commission in Massachusetts will have the right to prescribe only what shall be done by the private companies, if I am correctly informed, and its adoption by municipal plants would be entirely optional. In Maine the Commission has control over publicly owned utilities as well as privately owned, and the cities must report on these forms just as much as private companies. Is there any further discussion?

Mr. MacKenzie. The schedule of accounts submitted was drawn so as to be adaptable for use by large as well as small plants. Take, for instance, page 64. The accounts shown on that page might be the only ones that small plants would use. They would not have to subdivide their accounts as they are subdivided on the later pages of the report for large plants.

If you will go over the reports of various municipal departments, and even some private companies, you will find that they have simply kept a cash account, which is about the end of their accounting, and from that cash account you couldn't tell how much it is costing them to deliver water. They have taken no account of depreciation or the other various items that enter into the cost of their water supply. I hope that the report as a whole will not confuse any one and make them think that it is too complicated to be adaptable to smaller plants; for it is intended to be flexible enough for any water works to use.

I have here a schedule, such as we are using in a certain private plant; on the front side of the sheet appear the assets and liabilities, also the profit and loss for previous years and for the current year, and on the back side of the sheet appears the statement of receipts and expenses for the period which the report is made out for, and the net gain for that period, which should equal the net gain shown on the other side; such a system really gives a double set of double-entry book-keeping and usually checks any errors. And right from that report it is very easy, knowing the quantity of water you are furnishing, to determine what it is costing you for the various items. I would be glad to have the members look this schedule over and suggest any improvements which they may think could be made in it.

Mr. W. C. Hawley.* I had quite a little experience in connection with the preparation of the uniform system of accounting which has been adopted by the Public Service Commission of Pennsylvania. Such systems do seem very elaborate and confusing, but they can be simplified by the smaller companies and they can be elaborated as may be desirable for the larger companies. These are matters of detail to be worked out by the individual, although our commission has made four separate classifications for water companies based upon the total annual revenue. There is a very simple classification for companies with a total annual operating revenue of $5,000 or less; one which is more elaborate for companies whose total annual operating revenue is more than $5,000 but not more than $50,000. The next classification is based upon a revenue of more than $50,000 but not more than $250,000, and the next applies to those companies whose revenue exceeds $250,000. Some of the other state commissions have done the same thing.

But the important thing, and the thing which has been overlooked in the past by most water companies at any rate, has been to keep their accounts in such shape that when it came to a rate case, or a valuation of their plant, they could turn to their books and show what their plant was worth. Those engineers who have had occasion to go through the books of companies to try to dig out the information and find what the plants actually cost, realize what the difficulties are. Quantities and units price are not there. Time books and pay-rolls cannot be analyzed. Items that should have been charged to maintenance have been charged to construction, and vice versa, etc.

There is one thing about this classification to which I would call particular attention. I have not studied it carefully, — in fact I have only looked it over hastily, — but I have found no place for carrying as an asset the depreciation reserve fund, or replacement fund. Now, let us make a distinction between the fund and the "reserve." I do not know why the accountant uses that word "reserve." We generally, in ordinary language, put a different meaning on it from what the accountant does. In Pennsylvania they are carrying the reserve as a "red" asset. That is, they have taken it from the liability side and put it on the asset side as a "red" asset, immediately under plant value, so that by making the subtraction we get at once the depreciated value of the plant. Now, if you are going to maintain the investment — and that is the vital thing for a water company and those who invest in its securities who have to go before a commission and justify its rates — you must carry a fund to offset the accrued depreciation. It will be said, "Why, you are taking that money and you are investing it in plant" — although you can't have it invested twice. You have invested it once in the original plant, and you are setting it aside year by year to offset the accumulating reduction in value of your plant and to have it ready to make replacements with as units of the plant become

*Chief Engineer, Pennsylvania Water Company.

no longer useful. If you put it into plant and carry it there, then you are simply reducing your investment that much and there is no available fund for replacements.

This has been recognized by the Wisconsin Commission, by the Commission of Indiana, and some of the other commissions. The Commission of Oklahoma has recently prepared, but not yet issued, an order by which all utilities would be compelled to carry a depreciation replacement fund, to take the money which is set aside year by year from depreciation and create an actual fund, that fund to be invested and to be available to make replacements as they may become necessary.

If we invest this money in plant, two things will happen. First, we will have the public service commissions rule, just as they have in cases all over this country, that your plant cost so much, or its value new is so much, and they subtract accrued depreciation and so arrive at the present value of the physical plant. If the company does not have in hand a fund representing that accrued depreciation, just that much of its investment is wiped out. It has no fund to offset it; that much is gone. So that if we are going to protect our investment it is of vital importance that the fund should be created and should be carried.

In the second place, there will occur what happened to one of our companies within a year or two. We had a very expensive pumping engine which had outlasted its usefulness and had to be replaced. Fortunately, we carry a replacement fund and had the money available with which to replace it. If we had been putting that money into our plant we would not have had money enough for two or three years, from what we set aside annually for depreciation, to replace that pumping engine.

I believe that this is a matter which merits serious consideration, from private water companies particularly. Municipal water departments may arrive at satisfactory results by creating sinking funds with which to reduce bonded indebtedness, and when replacements are necessary can issue new bonds. Water companies could do the same thing in the past, but not now. They are under commission regulation to-day, with rules prescribed for this and orders laid down for that, and rates of return limited to such an extent that the companies find it exceedingly difficult to secure new capital for extensions and betterments. The companies should, therefore, do what they can to remove the difficulties of securing new capital, and there is no more practical way than to protect as far as possible the capital already invested.

In this connection I call attention to the decision of the Wisconsin Railroad Commission in the case of Milwaukee Electric Railway and Light Company *et al. v.* City of Milwaukee (P. U. R. 1918, E. p. 1) and that of the Indiana Public Service Commission, *re* United Public Service Company of Rochester, Ind. (P. U. R. 1918, F. p. 316).

PRESIDENT SHERMAN. I might say, Mr. Hawley, that in the suggested system of accounts, although the account does not appear by name, it

would lend itself perfectly well to carrying that under Account 26, "Miscellaneous Current Assets," which, of course, in such a system as you describe, would carry a name opposite that particular account showing what it was, — that is, depreciation fund, or depreciation investment.

MR. HAWLEY. That is what happened in Pennsylvania. We could not convince the accountant at the time that this was necessary. Later we were directed to carry the account as a sub-account under Account 113, "Insurance and Other Reserve Fund Assets." This is a separate, distinct fund, like the compensation insurance fund, fire insurance fund, and this particular fund we designate "Depreciation of Structures and Equipment Replacement Fund."

PRESIDENT SHERMAN. The Maine Utilities Commission has a special number for that account. As I remember the name for it, it is "Depreciation Reserve Invested," or something of that nature. But it would fit into this particular system of accounts under that general number, with the appropriate name under a subdivided head.

MR. MACKENZIE. I think Account No. 24 would take care of that, — "Cash (Special Funds)." That account can be subdivided into the reserve funds for engines, pumping station, pipe lines, or whatever account special circumstances might require.

PRESIDENT SHERMAN. Of course the "Depreciation Invested Fund" would be indicated as such in the particular account to show what it was.

MR. GEORGE A. KING.* I would like to ask Mr. MacKenzie if he can tell us how nearly these accounts agree with the accounts which were reported by the committee of the American Association about ten years ago, made under the direction of the Census Bureau?

MR. S. H. MACKENZIE. I can't tell you from memory the difference, now.

PRESIDENT SHERMAN. Is it safe to say the general principles are identical?

MR. MACKENZIE. Yes.

MR. EDWARD D. ELDREDGE.† I should like to ask for information on one subject. If some of the surplus is not used for extensions, and charged off as a depreciation, possibly, from what source is the money to come for extensions or new work in the line of extensions? Would that call for a new issue of stock or money borrowed?

PRESIDENT SHERMAN. It would have to come from some source, obviously, — either from issue of new securities or, in case of municipal plants, by appropriations from taxes, or from donations, if such were available — I have heard of such things.

MR. HAWLEY. The Indiana Commission permits the company to borrow temporarily from this fund for extensions. I think there is a limit as to the time that money may be had.

* Superintendent, Water Works, Taunton, Mass.

† Superintendent, Onset, Mass., Water Company.

Mr. S. H. MacKenzie. I think if that could be done, perhaps the plan mentioned by Mr. Hawley would be effectual. Our commissioners have objected to setting aside in cash the total reserve for depreciation, because during a period like we have been going through the last four or five years, if we could not have used our reserve fund for new work, but had had to go out and borrow money at an excessive rate, it would have made quite an inroad on our income. We would have received but about four per cent on our reserve and might have had to pay seven or eight per cent. Their contention is that, if the money is invested in the plant and the plant made to earn a sufficient gain to take care of the reserve for depreciation, they were carrying out the right principle. There should be no trouble in renewing our bonds if our plant has earned all expenses, including depreciation; whether the depreciation is in cash or actual new construction, it will cost more to finance new construction a few hundred dollars at a time, than to renew an issue of bonds of a large amount with an efficient plant back of them.

President Sherman. Is there further discussion? Are you ready for the motion? (*The question was put and carried.*)

President Sherman. Is there anything further to come before this session of the convention?

Mr. S. H. MacKenzie. I think, as this report has been adopted, that it might be wise for this convention to continue the committee, directing it to place this matter before the public utilities commissions of the New England States for their approval or suggestions, so that we may secure a uniform system for all of these states if possible.

Mr. S. H. MacKenzie. I therefore offer the following motion, viz., that the Committee on Uniform Accounting be hereby continued, and is requested to send a copy of its report of September 9, 1920, — containing the "Classification of Uniform Accounting for Municipal Water Works" this day adopted by resolution of the New England Water Works Association as a standard,—together with a copy of such resolution,—to each of the public service or utilities commissions of the several New England States, and to ask the coöperation of such commissions in the recommended use of the general scheme of such accounting classification. (*The motion was seconded, put, and carried.*)

Mr. A. R. Hathaway * (*by letter*). As a member of the accounting committee I have been much interested in reading the proof of the discussion pertaining to adoption of report and accounting classification submitted in 1920 by the Committee on Uniform Accounting for Municipal Water Works, and have been somewhat surprised and pleased at the absence of vital criticism of the scheme. What little criticism was attempted appears to have been due to a lack of understanding of the report and failure to carefully study the classification offered. Being unable to be

* Water Registrar, Springfield, Mass.

present at the discussion, I am submitting the following as of some possible assistance to a better understanding of the matter.

It should be borne in mind at the outset that the report and classification are not to be considered as a complete text-book of detail (similar to the printed pamphlets of accounting systems prescribed and issued by the various public utility commissions of the country for use by the private utilities), but rather as a *composite outline* of the principal and fundamental accounting results needed to be obtained, as indicated in some of the best of these prescribed systems, and as gathered by a study of the same.

With this in mind, the entire accounting scheme can be more easily and simply followed and understood by *first considering only the three principal statement results* to be accomplished, as shown in *condensed forms* on pages 64, 70, 74 of the report as printed in the JOURNAL for March, 1921; the supporting items suggested for same can then be found *indicated* in the detail pages following each condensed statement form; these supporting items can be used or varied to any extent wanted without affecting the integrity of the scheme, or the results to be obtained (as shown on the three pages above referred to); thus allowing any degree of flexibility in the use of the classification.

It should be impressed upon the officials of the smaller municipal water works, and also upon those who may not be so familiar with accounting, that the seeming mass of subdivisions and subaccounts, partially indicated as supporting the three essentials above referred to, are *not the essentials* themselves, and should not be allowed to confuse their minds at the outset of their consideration of the scheme. In fact, if all the municipal water-works operators could have their accounting officials keep *only the group accounts* shown on page 64 (Income and Profit Loss Condensed Statement Form), they would then obtain the uniform results essential for operating comparisons with each other, and, knowing the total quantity of water supplied, be able to easily show the cost per million gallons furnished, and the proportional percentage of such cost for each of the several group accounts or logical processes of operation.

Likewise the essential results in Assets and Liabilities could be shown in uniform manner by using *only the group accounts* suggested on page 70 for Condensed Balance Sheet Accounts. The Condensed Form for Cash Summary, on page 74, needs no further comment or explanation.

By approaching the matter in this simple but comprehensive way, I cannot see how any one should get the impression of the scheme being elaborate, for it was the purpose of the committee to avoid giving such an impression, as is usually obtained by a *first reading* of the text-book classifications prescribed by the various public utility commissions of the different states for the private utilities, without a further study of such classifications.

One thing that should be kept in mind (which in the discussion was apparently lost sight of at times) is that the submitted classification is

intended primarily for *municipal* water works, as those privately-owned are already operated under uniform accounting requirements of the different state commissions, as elsewhere referred to.

Regarding the matter of depreciation and treatment of same in connection with public utility accounts, there are an increasing number of opinions being handed down by public utility commissions and other authorities, and, while many differing views are expressed as to details, there appears to be practical agreement as to the principal accounting requirements. As I understand the matter such requirements applicable to *municipal utilities* seem to be about as follows: the plant or property assets are carried on the books at the full amount of outlays made, or on a cost basis entirely; proper depreciation charges (on tangible depreciable portions of such assets) are to be included in the operating expenses of each year, being debited to same at regular stated intervals, and thus distributing this burden of certain costs evenly throughout the estimated life of such assets. As such charges to operating expenses each year in effect actually reduce the otherwise gain or surplus account of that year by the same amount, such reduction, reservation, or appropriation, from the book surplus account (which is a liability account), should be carried as a separate *reserve* or appropriation account (liability, of course), against which all future replacements of such property assets (on original cost basis) should be charged as they occur; by this procedure the original cost of all replaced property units is by that much *restored* or kept in the property assets without disturbance of such assets; the balance left in the liability reserve account will at any time represent the amount of estimated depreciation provided for and not yet replaced or made good in the property assets; and the difference between this balance and the total plant or property assets will then represent the net total of such cost assets which is assumed to have been kept up to date. This difference is not usually shown in the balance sheet, but when wanted can be easily drawn off in statement form.

As to the names or titles of the foregoing accounts, that is largely a matter of choice; the leading authorities appear to prefer "Plant, Property and Equipment" (for municipal utilities), or "Capital Installed" or "Fixed Capital Assets" (for private utilities), as the asset account for plant cost or investment; for the charges (debits) to operating expenses to take care of replacements, etc., "Depreciation," "Depreciation and Contingencies," "Depreciation Reserve Charge," etc.; for the appropriation or reserve account (liability) to show how much must be provided for future replacements, etc., "Depreciation Reserve," "Reserve for Depreciation," "Accrued Depreciation or Amortization," "Reserves," etc.

I am glad that in the discussion there was presented the matter of public utilities setting aside from revenues an actual *cash fund* to provide for payment of replacements, etc., due to depreciation. While this has not been a general requirement of public utilities (either private or municipal)

by all accounting authorities, it has lately been prescribed by a few of the utility commissions for private utilities, and is becoming more of an important element in rate cases, with an increasing trend in favor of adoption of such a requirement. As was stated in the discussion, if a sufficient gain resulted from operation it has been a question whether the asset value of such gain as should be reserved for depreciation replacements should be expressed in cash or in property. In either case the asset value is there, provided (as stated) that the utility is a self-supporting enterprise and is operated to produce the profit needed. Otherwise, either the revenues should be increased or the expenses diminished; and one great advantage in requiring an actual cash fund for this purpose is the absolute assurance that the utility is regularly reserving such security against the days certain to come.

On the other hand, the absence of such a cash fund need not necessarily mean that a municipal utility is not providing through its other assets such reasonable security as is practicable under its operating conditions. This is the way the matter appears to me at present, but I am in favor of having such a fund established if possible, and have so recommended to our Springfield Water Commissioners in my last annual report.

As stated in the discussion, ample provision is made in the accounting committee's classification for showing such a fund if wanted, under "XXIV. —Cash (Special Funds),"—or subdivision of same,—as found on page 70 of the report. Where such a fund is prescribed by some of state utility commissions, its temporary use for extensions and certain other purposes is to be allowed, provided such use is treated as a *loan* and repayment is made to the fund within a stated time limit. Interesting and valuable opinions upon this entire subject are being handed down by various public utility commissions throughout the country. As the space herein forbids quoting such opinions, a reading of the same is recommended to those having access to the "Public Utilities Reports, Annotated," especially the opinions found in the following references, viz.: — Arizona—P. U. R., 1920D (p. 613); California — P. U. R., 1920B (pp. 118, 119, 120, pp. 810, 811, 812); Idaho — P. U. R., 1915F (p. 445); Indiana — P. U. R., 1918F (pp. 329, 330, 331); P. U. R., 1920D (pp. 123–124), and P. U. R., 1920C (p. 280); Missouri — P. U. R., 1915C (p. 1017); Nebraska — P. U. R., 1920C (p. 505); Nevada—P. U. R., 1920F (p. 769); New York—P. U. R., 1920D (p. 274); Oregon — P. U. R., 1915D (pp. 855–909); Washington — P. U. R., 1920F (p. 956); Wisconsin — P. U. R., 1920A (pp. 362–394), and P. U. R., 1920D (pp. 434–435).

THE SIGNIFICANCE OF "HYDROGEN-ION CONCENTRATION" IN WATER PURIFICATION.

BY HARRISON P. EDDY.*

[*Read September 15, 1921.*]

The term *hydrogen-ion concentration*, for short written also "H-ions" and "PH," may with sufficient accuracy for popular purposes be paraphrased *concentration of acidity or alkalinity*, as the case may be. Pure water is neutral, — that is, neither acid nor alkaline; and its hydrogen-ion concentration is taken at 7. Acidity is designated by numbers below, and alkalinity by those above 7.

The acidity or alkalinity of a liquid has thus far generally been reported in terms of total quantity of acid or alkali present. It has commonly been determined in water by adding acid or alkali, of known strength, in sufficient quantity to neutralize the original acidity or alkalinity, the neutral point being indicated by a change in color due to a small quantity of organic dye previously added. But the action of the acid is not due solely to its total quantity but rather to its effective quantity or intensity. The essential difference between this old determination and the new hydrogen-ion method is that the latter shows the intensity, or true acidity, rather than the total quantity of acid.

The function of alum used in the process of water purification is to produce a coagulum, or floc, of relatively large size, capable of absorbing or enclosing the finely divided foreign substances which cannot be removed by practicable periods of sedimentation or by filtration at high rates. When absorbed by the alum floc, however, they may be removed readily by sedimentation or by filtration, or by both processes jointly. It is obviously important that the alum introduced into the water be converted into floc as completely as possible.

It has generally been supposed that the precipitation of the sulphate of alumina is dependent primarily upon the presence in the water of sufficient alkali, and that any excess of alkali likely to be present in waters generally used as sources of water supply is not disadvantageous. However, certain experiments indicate that there is an optimum point at which apparently all of the aluminum is thrown out of solution, but that above that point on the side of alkalinity or below it on the side of acidity precipitation is not complete. This offers a plausible explanation of the presence in the water being treated of aluminum both in insoluble and soluble form at the same time and of the frequent occurrence of dissolved

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aluminum in filtered waters. It certainly indicates that it may be highly important, if practicable, to carry out the coagulation process at the optimum point of alkalinity, — the isoelectric point. Without this determination, or its equivalent, it is impossible to know whether the water has the proper PH. It may be too low or too high for complete precipitation and it will probably only occasionally be just at the optimum point.

The presence of aluminum in two forms is explained by some according to the theory that the alum assumes a colloidal condition, by which is meant a condition intermediate between solution on the one hand and suspension on the other. Thus we may speak of salt dissolved in water, as a solution, and sand or fine silt suspended in water, as a suspension. The soap in soapy water may be taken as a popular illustration of the intermediate condition — that is, the soap is a colloid. Some substances, like the alum used in purifying water, may be in, or be changed into, any one of these three conditions. The change is one of condition rather than of composition.

Another theory is that the alum may exist as different chemical compounds, some of which are soluble and others insoluble.

Whichever of these theories may be accepted, the important point is that the alum can be converted completely into insoluble aluminum hydrate only within a narrow range of hydrogen-ion concentration, which is not indicated by the methods commonly used for determining alkalinity, and that either above or below this zone the aluminum, or a portion of it, may be present in solution.

It follows, therefore, that it is as important to reduce an alkalinity which is too high as to increase an alkalinity which is too low. This introduces a step in the process of the treatment of water which is not common and which may prove of material value.

It is hardly necessary to point out the fact that the hydrogen-ion concentration appertains to the condition of the water for satisfactory coagulation and is not a method for determining the quantity of coagulant required. This must be done as an entirely independent step in the process.

For ascertaining the isoelectric point the determination of the hydrogen-ions affords a convenient and practical means. This may be accomplished in a manner similar to that long used for the determination of the total quantity of acid or alkali present. Thus, by the use of several indicators constituting virtually a scale of indicators and by the addition of the proper quantity of alkali, or other compound, it is possible to bring the water to the exact hydrogen-ion concentration required for complete precipitation of the aluminum from the alum added to the water. Theoretically, this may be so minutely controlled in practice as to prevent the occurrence of dissolved aluminum in the presence of the insoluble aluminum floc.

As the difference in electrical pressure or potential between any metal and its ions varies with the concentration of those ions, it is possible to

determine this concentration by means of suitable electrical apparatus, one form of which is known as the "potentiometer." By the use of the hydrogen electrode,* therefore, it is possible to determine the concentration of the hydrogen-ions.

In order to take advantage of the hydrogen-ion concentration in the operation of a water purification plant, it will be necessary to control the chemical treatment according to several steps, such as —

1. Determine the quantity of alum required for successful treatment under conditions prevalent at the time.
2. Determine the PH of the water to be treated.
3. Determine the quantities and kinds of chemicals to be introduced, in order to bring the water to the isoelectric point for coagulation of the aluminum.

The procedure, then, would consist of adding the proper kinds and quantities of chemicals to produce the isoelectric point and the required quantity of alum for the successful treatment of the water.

The quality of most raw waters varies from time to time, — often materially within very short periods of time. This variation may be in bacterial content, organic matter, numbers of micro-organisms, turbidity, temperature. or in all of these. It is obvious, therefore, that the quantity of alum must be varied to meet the conditions at the time. It is highly probable, also, that the PH varies greatly and that the kinds and quantities of chemicals used to produce the isoelectric point must be varied accordingly. Even if the PH of the raw water remained constant, the necessary changes in the quantity of alum introduced would make it necessary to vary the chemicals required for producing the isoelectric point, as this condition must be fixed with reference to the quantity of alum used; or, in other words, if coagulation is to be complete the water must be at the isoelectric point after the sulphate of alumina has been added.

It has been suggested that the PH of the water may be determined and the application of the conditioning chemicals regulated automatically by electrical apparatus. Such equipment would greatly simplify the control of the process.

Among the advantages which may possibly result from PH control of water purification plants may be mentioned the following:

1. Prevention of passage of alum through filters and after-precipitation in mains.

The passage of alum either in solution or as a colloid through water filters has long been recognized as one of the defects of the alum treatment. Such water is not satisfactory for domestic consumption and is objectionable for certain industrial uses, such as dyeing. It may be possible by chemical treatment to so adjust the PH as to secure complete precipitation of the alum and prevent its passage through the filters.

* Because metallic hydrogen cannot be obtained, an electrode is used which is covered with spongy platinum saturated with hydrogen.

2. Prevention of corrosive action.

It is possible that the treatment of the water to secure the isoelectric point will reduce the danger of corrosive action by the filtered water, due either to the presence of dissolved aluminum sulphate or to excessive carbon dioxide. The treatment required to produce the isoelectric point in some cases (where acid is required) might not reduce — in fact, it might actually increase — the amount of free carbonic acid present in the water. It does not follow, therefore, that in all cases advantage can be taken of reduction of both of these corrosive substances, although it may be possible to so adjust this treatment as to accomplish this. It is conceivable and has been suggested, however, that in practice water treated in this manner might become more highly corrosive than that treated in the ordinary way.

3. Control of small plant and animal life.

It has long been known that the growth of microscopic organisms and bacteria is favored by the concentration of acidity, within certain limits, outside of which there is an inhibiting effect. It has been suggested that by securing the optimum PH for precipitation of alum, the environment of such organisms may be so changed as to prove detrimental to them and inhibit their growth. There is scarcely any definite information on this point and it is included herein merely as a suggestion of possible means of controlling growths in filter plants, which in some cases have been quite troublesome.

4. Possible reduction in size of filter plant.

It is a matter of common knowledge among chemists that precipitates formed under certain conditions settle and filter much more readily than those formed under other conditions. There seems to be ground for the belief that alum precipitated at the optimum PH point may form a floc which will settle more readily and permit of more rapid filtration than similar floc formed at a less favorable PH. Should it prove that coagulation at the isoelectric point will produce a floc which will coagulate and settle more readily and permit of a higher rate of filtration, a corresponding reduction in size of coagulation basins and filters might prove a substantial advantage. While it is conceivable that the change in the character of floc, due to PH control, might warrant a change in the depth of filtering material or in some other detail of construction, this does not appear at all probable.

5. Possible increase in efficiency of operation.

If coagulation at the isoelectric point will result in the formation of a better floc and in avoiding the passage of dissolved aluminum through the filters, it may be that the bacterial efficiency of filtration will be improved to some extent. It seems reasonable to expect such a result from observation of the process of coagulation.

While these and perhaps a number of other advantages of the PH control may be possible from a theoretical point of view or may be obtained in the laboratory, it is important to prove to what extent, if any, they can be secured in the practical operation of water purification plants.

There is little doubt that the determination of the hydrogen-ion concentration will permit of a more intelligent study of the water and the reactions taking place during its treatment. This fact alone is sufficient to warrant making a thorough investigation of the subject and determining the PH value in many cases.

It is possible that the methods of control now in use, based in part upon the older conceptions of the chemistry involved and in part upon practical operating experience, permit of as close operation of purification plants as it is possible to obtain, even with the assistance of the more delicate and refined hydrogen-ion determinations made in accordance with the latest theories of chemistry.

It often happens that empirical methods lead to practical results which are as satisfactory and effective as those based upon more accurate knowledge. This fact, however, does not justify disregard of progress in science and of new theories. It cannot be gainsaid that the older practitioners in any profession, or in the arts, are inclined to adhere to the older methods and processes as a result of their familiarity and experience with them and a natural reluctance to adopt new ideas. The older members of the profession should constantly guard against this tendency, in order that valuable improvements may not be ignored, simply because they involve new discoveries and new theories.

While it is wise to give proper weight to the reasonable doubt of success in order not to be misled by theoretical considerations, it is certain that the subjects of coagulation and filtration should be very thoroughly studied in the light of the more modern chemical theories. Such investigations will lead to a better understanding of the chemistry of coagulation than that which has governed this important subject in the past. With improved conception of the process, advantages of more or less importance are likely to follow. The true value of the hydrogen-ion determination can only be learned through investigations covering a great variety of conditions encountered at a large number of plants.

Such investigations may well lead to a re-study of the whole subject of chemical treatment of water, and improvements may result in lines entirely apart from the hydrogen-ion determination, which furnished the initial incentive for such further study.

Discussion.

Mr. Harry W. Clark.* I believe that we all can study this matter, and I think quite a few of us will know more about it in a year or two than we do now. It is a very delicate method, and a rather scientific and involved method, covering water filtration, but I have no doubt something will be worked out along practical lines, started by this method. We certainly ought to know more about the methods by which we get the best purification. We all of us have many difficulties. We have found alum coming through, alum in solution, and so forth. If this is going to lead us out of our difficulties it certainly is a great advance. Mr. Eddy has covered about everything that we know at the present time.

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* Chemist, Massachusetts State Department Public Health.

MR. FRANK W. GREEN.* The heaviest floc is not always the most desirable, because at times a very heavy floc is apt to break up on its way to the filters on account of being less cohesive than a lighter floc. This breaking up of the floc may allow the passage of some of the aluminum hydroxide through the filter beds. We are making a number of studies covering the PH value and the more important mineral constituents, to determine their relation to the character of the floc.

One of the controlling factors of coagulation is the carbonic acid. The simplest way of getting rid of carbonic acid is aëration. Formerly we tried to get rid of all the carbonic acid, but it appears probable that at times we will get better results by removing only a portion of it.

The impression that I got from Mr. Eddy's paper was that the iso-electric point was identical with PH-7, or the neutrality point. This is far from being the case. The isoelectric point in certain acids may be as low as PH-3, which is a thousand times PH-7. I have in mind a water having an alkalinity of 45. The PH value of this water is less than the isoelectric point, and lime must be added to get it to the proper point for coagulation.

I have here some notes on hydrogen-ion concentration which present a different view of the same subject:

The actual determination of the PH value of a given water is one of the most simple tests that the water analyst has to perform, provided he takes advantage of the permanent standards and indicator solutions now on the market. The test consists in adding a few drops of the indicator to the water sample, and comparing its color to that of the standards. What could be more simple! This is the colorimetric procedure which has been developed to its present state of perfection and simplicity by the scientist.

The study of the theoretical side of hydrogen-ion concentration is very complex and difficult, and should be undertaken only by one possessed of a thorough knowledge of dye-structure, spectroscopy, physiological optics, and electrolytic dissociation. For instance, in deciding on a method for the colorimetric determination of the PH values of a certain zone, many indicators must be examined and their various advantages and limitations compared. Numerous electrometric experiments of extreme delicacy must be patiently performed.

However, after the proper formulas have been worked out, solutions of definite values can be readily duplicated by any one who has the requisite technique, even though he may have absolutely no theoretical knowledge of the subject. These solutions can be used by any one who is not color blind and can count to ten.

Hydrogen-ion determination, as applied to natural waters, is the measurement of the minute amount of hydrogen which is present in the

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ionic state due to electrolytic dissociation. Pure water has a value of PH = 7.0, but natural waters may vary from 6.0 to 8.0 (1 part to .01 part per billion). Although present in almost inconceivably small quantities, its determination is of considerable value because coagulation, corrosion, and other important reactions take place in definite zones of hydrogen-ion concentration. The result obtained for any given water depends upon the proportions of the contained amounts of certain acids and bases, those of greatest influence in normal supplies of this region being the free carbonic acid and the bicarbonates. So important are these two constituents that 3 CO_2 divided by HCO_3 will give a rough approximation of the H-ion concentration.

Although intimately related to the acidity and alkalinity, the following shows that it is a separate and distinct feature governed by rules peculiar to itself:

> "A liter of normal acid becomes fifth normal if we dilute it five times. . . . If we were to add to 1 liter of perfectly pure water of PH = 7.0, 1 cc. of N/100 HCl the resulting solution would be about PH = 5.0. . . . If, on the other hand, we were to add this same amount of acid to a liter of standard beef infusion medium of PH = 7.0, the resulting change in PH would be hardly appreciable." (W. M. Clark.)

The acidity varies proportionately, or nearly so, in all cases to the amount of HCl present; the PH value becomes one hundred times as large in the first instance where no salts are present, and changes scarcely at all where there is a "buffer" present. This inhibition of PH change is called "buffer action," and is of importance in several water-supply problems.

The pioneer investigators of the early '90's, for reasons of their own, chose to express their results in terms of the logarithm of the reciprocal of the grams of ions present in one liter. This term is now known as the PH value. For general theoretical work where there is a wide field to be considered, say from PH = 2.0 (which is the hundredth of a gram) to PH = 11 (which is the hundred billionth part), it is undoubtedly of considerable convenience. For our work which lies in the zone PH 6.0 to 8.0 (1.000 to .010 p.p.b.), it would appear that direct readings in parts per BILLION would be more readily comprehended by the practical water-works man. Also it would bring out more clearly that PH = 7.0 is ten times greater than PH = 8.0; which fact in itself is somewhat confusing to the non-mathematical mind. This term might be named the HB value, to show its relation to the PH values which have become accepted and will probably be retained in purely scientific investigations.

The following table gives the zone of concentrations commonly encountered in water supply investigations and routine analyses. Column A gives the PH value and Column B gives the HB value which is also the H+ equivalent in parts per billion, or, mathematically $(H+)^{-9}$ or $(1/H+)^9$.

(A) PH Values or (Log 1/H+).	(B) H-ions (Hb) p.p. bil.	(A) PH Values or (Log 1/H+).	(B) (Hb) or H-ions p.p. bil.
6.0	1.000	7.0	.100
6.2	.630	7.2	.063
6.4	.400	7.4	.040
6.6	.250	7.6	.025
6.8	.160	7.8	.016
7.0	.100	8.0	.010

For routine work, quite accurate results may be obtained by the use of the sets of Brom thymol blue standards with a range 6.0 – 7.6 and phenol red series of 6.6 – 8.2 in sealed test-tubes. Bottles of solutions of the two indicators, and color charts to insure that the standards are correct, can also be purchased for a small amount. Take 10 cc. of the water to be tested, add a few drops of the indicator, and compare with the permanent standards. Each one of us should familiarize himself with at least the broader aspects of this fascinating subject, and those who can do so should add to the data that is being collected for further study and interpretation.

Mr. Stephen DeM. Gage.* The question of the hydrogen-ion concentration of water is so new as a practical water-works proposition that I have had little opportunity to look into it. After listening to Mr. Eddy's very clear exposition of its possibilities, especially in connection with filtration and corrosion, it has come to me that perhaps a study of the hydrogen-ion concentration may point the way to a solution of a problem which has been bothering us for some time.

We have had trouble in the operation of one of our rapid sand filter plants practically ever since it was started, some ten years ago. In the summer we could get good coagulation using alum and soda, and make good water. In the winter, however, it has been very difficult to get a floc which we could hold on the filters. After two or three hours, the beds seem to become porous and the color and turbidity of the effluent would rise rapidly. The only way the filter operator can make good water at such times is to take frequent color readings on the effluent and wash a filter as soon as the color begins to come through. We have tried everything we could think of to overcome this difficulty, but so far we have failed to solve the problem satisfactorily, but we have always believed that the trouble was due to some peculiarity in the water which we were trying to treat. When this condition occurs again, as it is sure to occur about the first of December, we are going to try to work it out along the lines of this new theory, and hope this will prove the solution for which we have been looking.

Mr. Eddy. I want to thank Mr. Green for calling attention to that apparent error. I did not intend to give the impression that the isoelectric point is coincident with 7. In some of the work we have been doing the

*Chemist and Sanitary Engineer, R. I. State Board of Health.

isoelectric point is about 3.5. The isoelectric point varies with the material which is to be coagulated and precipitated.

Another interesting fact with reference to some materials is the so-called "drift." In the material to which I have just referred, which appears to coagulate best at a PH of about 3.5, which is obtained by adding sulphuric acid, there is a rapid drift, so that in the course of an hour or two the material has drifted back from 3.5, or thereabouts, to a point perhaps as high as 6. At this PH, the material acts in a very different manner from that at a PH of 3.5. It is possible to overcome this difficulty, in a measure, at least, by treating the material with an excess of acid, to bring the PH below the isoelectric point, so that the liquid will not drift back far beyond the point most advantageous for handling the colloids within the time available.

Another rather interesting experience has been with the potentiometer, by means of which the PH value can generally be determined electrically. In certain tannery liquids, it has been found that the hydrogen electrode is very quickly "poisoned," so that it becomes absolutely useless. The color indicators, however, appear to give correct results. They agree with those obtained by the potentiometer, provided it is manipulated with sufficient rapidity to secure the results before the electrode becomes "poisoned." While the potentiometer is not adapted for practical use in that liquid, there does not appear to be any reason why it would not be practicable for waters used as sources of domestic supply. It is, however, a very delicate instrument, and, as now constructed, it appears to be better adapted for laboratory research than for field investigations.

A promising use for the hydrogen-ion control in the purification of water is in the industries where a high degree of purity or the absence of certain chemical compounds is necessary, such as in dyeing. In one such plant which has come under my observation, there were occasional difficulties in dyeing, for which the only explanation seemed to lie in the quality of the water used, notwithstanding the fact that the water was so purified that it did not cause such difficulties during a large proportion of the time. It may well be that more complete control of the hydrogen-ion concentration would provide a water so purified as to be satisfactory for the dyeing process at all times.

REPORT OF THE COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

Discussion.

(Past President Samuel E. Killam takes the chair.)

Mr. Charles W. Sherman. Mr. President, I assume it is not necessary to go to any extended discussion in presenting this report. It was printed in the June issue of the Journal, page 187, and represents a very considerable amount of work on the part of a joint committee, consisting of a committee appointed by this Association and one appointed by the American Association. Perhaps I may take a minute to briefly review the appointment and work of the committees without reading the specifications.

Mr. Robert J. Thomas presented a brief paper at our convention in Portland, in 1916, calling attention to the desirability of uniform standard specifications for meters, and as a result of his paper a committee was appointed by our Association. In 1919 the American Association voted to establish a similar committee, which was done at once, with our past president, Mr. Saville, as its chairman. Our committee had not done much work prior to that time, although some correspondence had been had, but war conditions prevailed nearly the whole period prior to 1919 and made it seem impracticable to accomplish any real results, and of course all of us were extremely busy.

In 1919, however, the time seemed ripe to really do something, and a joint meeting of the two committees was called, which was attended by substantially the whole membership, and at that meeting I was chosen as chairman of the joint committee and it was decided that the two committees should work jointly as a single committee. Mr. Brush, who is chairman of our own committee, acted as a representative of the committees in the sessions of the Meter Manufacturers Association, which was discussing the same thing, and which drafted for our consideration suggested specifications, which of course were discussed in Mr. Brush's presence and worked out in preliminary form before they came before our joint committee. We discussed them in considerable detail, and they went back to the manufacturers and were revised and sent to us again and were adopted in, I think, a form which was acceptable to every member of the committee, and, as far as I am informed, thoroughly acceptable to the manufacturers.

The specifications have been made as simple and general as it seems possible to make them, and still we think are explicit on the points of prime importance. They cover only disk meters, and therefore are not a complete performance of the duty entrusted to the committee. We hope that we

shall be able to complete the work by passing on specifications for the current type of meter and compound meters eventually; but it seemed to the joint committee wiser to get a disk meter specification adopted and tried out at least for a brief period, before recommending other specifications covering other types.

The specifications, as most of you know, were presented to the American Association at its convention this year, and were adopted without modification. The American has but its one meeting a year, which is the convention, at which such action can properly be taken, and, as you know, theirs came earlier than ours.

The specifications are now submitted to this Association for action, and I believe that the Association is fully warranted in accepting them as they stand.

Mr. J. M. Diven. I understand that the committee has discussed this very thoroughly and taken it up with the manufacturers, and that their specifications are practical. Their report is so complete and so conclusive that there does not seem to be any room for discussion.

Mr. George A. King.* I do not think that the specifications quite cover one point. I should like to see a clock on a five-eighths meter, the maximum reading on which was only 10 000 instead of 100 000. Those who read their meters frequently would find that a desirable feature. Probably those who do not read them frequently would want one whose maximum reading was 100 000, as the report calls for.

Mr. R. K. Blanchard.† *Mr. Chairman and Members,* — The Manufacturers' Committee was appointed at the request of your Association. We spent a great deal of time in preparing these specifications, and endeavored in every way to meet the demands of the water-works superintendents and the operators. We changed many things in the construction of the meters, which made all the different manufacturers change something to have a uniform specification. The specification as it stands to-day, from the manufacturers' point of view, is very satisfactory.

I think that we do not appreciate how much a real standard specification on water meters means. The manufacturers receive specifications on which to bid on meters, and I venture to say there are not two specifications which are exactly the same, both as to tests of meters and construction, and in this specification your committee has demanded of the manufacturers a meter that will answer all general requirements as to test and construction, and as far as the manufacturers are concerned the specification as it stands is very satisfactory. It protects not only the water-works operators, but also gives the manufacturer a definite goal which he has got to meet; and the manufacturers, I am sure, would be very glad to have this specification adopted. And on that point I hope that we

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† Chief Engineer, Neptune Meter Company.

can in some way get this specification before the members of the New England Water Works Association so that they will use it.

[It was voted that the report of the Committee on Standard Specifications for Water Meters be accepted and adopted, and the committee continued.]

RAINFALL IN NEW ENGLAND.

Corrections in tables published in June, 1921, JOURNAL:

Bloomfield, Vt. Average rainfall should read: July, 4.95; November, 2.26; Annual, 37.85.

Cavendish, Vt. Average rainfall should read: December, 2.75; Annual, 36.49.

Wilmington, Vt. Average rainfall should read: January, 3.28; February, 4.23; March, 4.43; April, 2.12; May, 4.80; June, 4.40; July, 2.44; August, 4.33; September, 4.74; October, 4.42; November, 4.19; December, 4.28; Annual, 47.66.

Ashland, Mass. Average rainfall should read: October, 3.43; December, 3.87.

Bedford, Mass. Average rainfall should read: May, 3.12; July, 3.35.

Danvers, Mass. Average rainfall should read: August, 3.06; September, 3.17; December, 2.92.

Hingham, Mass. (Accord Pond.) Average rainfall should read: January, 3.29; May, 3.74; July, 3.67; September, 6.48.

Leicester, Mass. Average rainfall should read: May, 3.39; Annual, 43.38.

Warren, Mass. Average rainfall should read: April, 3.35; July, 4.65.

Williamsburg, Mass. Average rainfall should read: April, 3.71; July, 3.93; October, 3.27.

AWARD OF DEXTER BRACKETT MEDAL.

MR. SAMUEL E. KILLAM. *Mr. President and Fellow-Members,* — We again meet to honor the memory of Dexter Brackett, whose wise counsel and sound advice were always acceptable to and respected by the members of the New England Water Works Association.

Mr. Brackett was born in 1851, elected a member of this Association in 1885, its president in 1890. His deep interest in the organization continued unabated until his death in 1915.

You will recall the tall, kind-hearted man who made many and valuable contributions to water-works literature, all of which are recorded on the pages of our JOURNAL.

It was my good fortune to serve many years under the direction of this honest and clear-headed engineer.

It is now my pleasure, as chairman of the Committee on Awards, to present the Dexter Brackett Memorial Medal for the most meritorious paper published in the JOURNAL for the year 1920.

It is needless for me to say to you who have studied this volume of the JOURNAL, that it was by no means an easy task for your committee to make its recommendation to the Executive Committee, but, in compliance with Rule 4, under which this award must be made, namely, "The medal shall be awarded for the paper which is judged to be most meritorious, bearing in mind its applicability to general water-works problems," we decided that the paper entitled "Lead Poisoning by Water and Its Prevention" was the best paper published in 1920.

I, therefore, take great pleasure in presenting to Robert Spurr Weston this medal. It is needless for me to say more, as the article speaks for itself of the time, thought, and study required in its compilation.

In the absence of Mr. Weston, I will turn this medal over to the President for safe-keeping. [Handing medal to President Sherman.]

MEMOIR OF CHARLES EDWIN HABERSTROH.

Born in Boston, Mass., February 14, 1849.
Died at Framingham, Mass., September 21, 1921.

Mr. Haberstroh joined the New England Water Works Association January 10, 1900, but was not a frequent attendant at its meetings. He was attached to the Sudbury system of the Boston Water Works as engineer, later coming under the control of the Commonwealth of Massachusetts, from 1874 to 1919, when he was retired. His most fitting eulogy is the resolution passed by the Metropolitan Water and Sewerage Board on his retirement, which we quote in full:

"In the retirement of Charles E. Haberstroh, superintendent of the Sudbury Department, which occurred February 13, 1919, the Board feels that the Commonwealth has lost a capable and faithful servant, who has rendered useful and important service in the construction and maintenance of the Metropolitan Water Works. Mr. Haberstroh was connected with the Water Works Department of the City of Boston for many years prior to the acquisition of the works of the city by the Commonwealth, and had a comprehensive and practical knowledge of the Sudbury Department, of which he was appointed assistant superintendent by the Board at the time of the taking of Boston's water works, in January, 1898. In February, 1907, he was promoted to the superintendency because of his knowledge of the Sudbury Department, and held the position until his retirement. His employment of more than twenty-one years has been characterized by faithful devotion to the work with which he was entrusted and untiring zeal in the discharge of the many and arduous duties devolving upon him.

FREDERIC I. WINSLOW.